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MX SITING INVESTIGATION, PRIME CHARACTERIZATION

FEB 79

FN-TR-268-REV

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SITES, SOUTHERN--ETC(U)

F04704-77-C-0010

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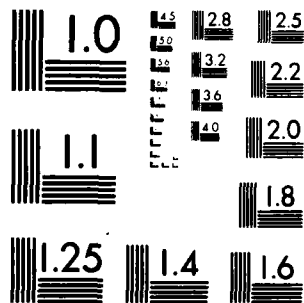
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MX SITING INVESTIGATION GEOTECHNICAL SUMMARY

PRIME CHARACTERIZATION SITES SOUTHERN HIGH PLAINS CANDIDATE SITING PROVINCE

**PREPARED FOR
SPACE AND MISSILE SYSTEMS ORGANIZATION (SAMSO)
NORTON AIR FORCE BASE, CALIFORNIA**

FUGRO
NATIONAL, INC.
Consulting Engineers and Geologists

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MX SITING INVESTIGATION
GEOTECHNICAL SUMMARY
PRIME CHARACTERIZATION SITES
SOUTHERN HIGH PLAINS
CANDIDATE SITING PROVINCE

Prepared for:

U. S. Department of the Air Force
Space and Missile Systems Organization
(SAMSO)
Norton Air Force Base, California 92409

Prepared by:

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3777 Long Beach Boulevard
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29 September 1978
15 February 1979 (rev.)

PRIME CHARACTERIZATION SITES
SOUTHERN HIGH PLAINS CSP

ERRATA

✓ Replace the following figures with revised ones which accompany this sheet: Figures 5 (p. 15), 6 (p. 17), 11 (p. 34), and 12 (p. 35).

✓ Replace the following tables with revised ones which accompany this sheet: Tables 5 (p. 18), 6 (p. 19), 12 (p. 36), and 13 (p. 37).

The following corrections are to be made to the original text:

✓ page 6, Section 2.2, line 6: Change "...degress..." to read "...degrees..."

✓ page 10, Figure 2: Generalized geologic map base revised, see Figure 6.

page 28, Figure ⁸28: Generalized geologic map base revised, see Figure 12.

✓ page 29, line 3: Add sentence between "...five percent." and "Excavatable rock...". Sentence to read, "The Ogallala Formation is considered to be a non-rock unit, but it locally contains well-indurated caliche caprock."

✓ page 29, line 3: Change "Excavatable..., and..." to read "Excavatable rock consists of..."

FOREWORD

This report was prepared for the Department of the Air Force, Space and Missile Systems Organization (SAMSO) in compliance with conditions of Contract No. F04704-77-C-0010, and is a geotechnical summary of the two prime Characterization sites in the Southern High Plains Candidate Siting Province (CSP). The two sites are Muleshoe, Texas and Roswell, New Mexico.

The report presents representative data obtained from geotechnical field investigations performed at both sites as part of the Characterization program. The information obtained from these studies, in combination with data obtained in the Screening studies, has been used for geotechnical ranking (FN-TR-25).

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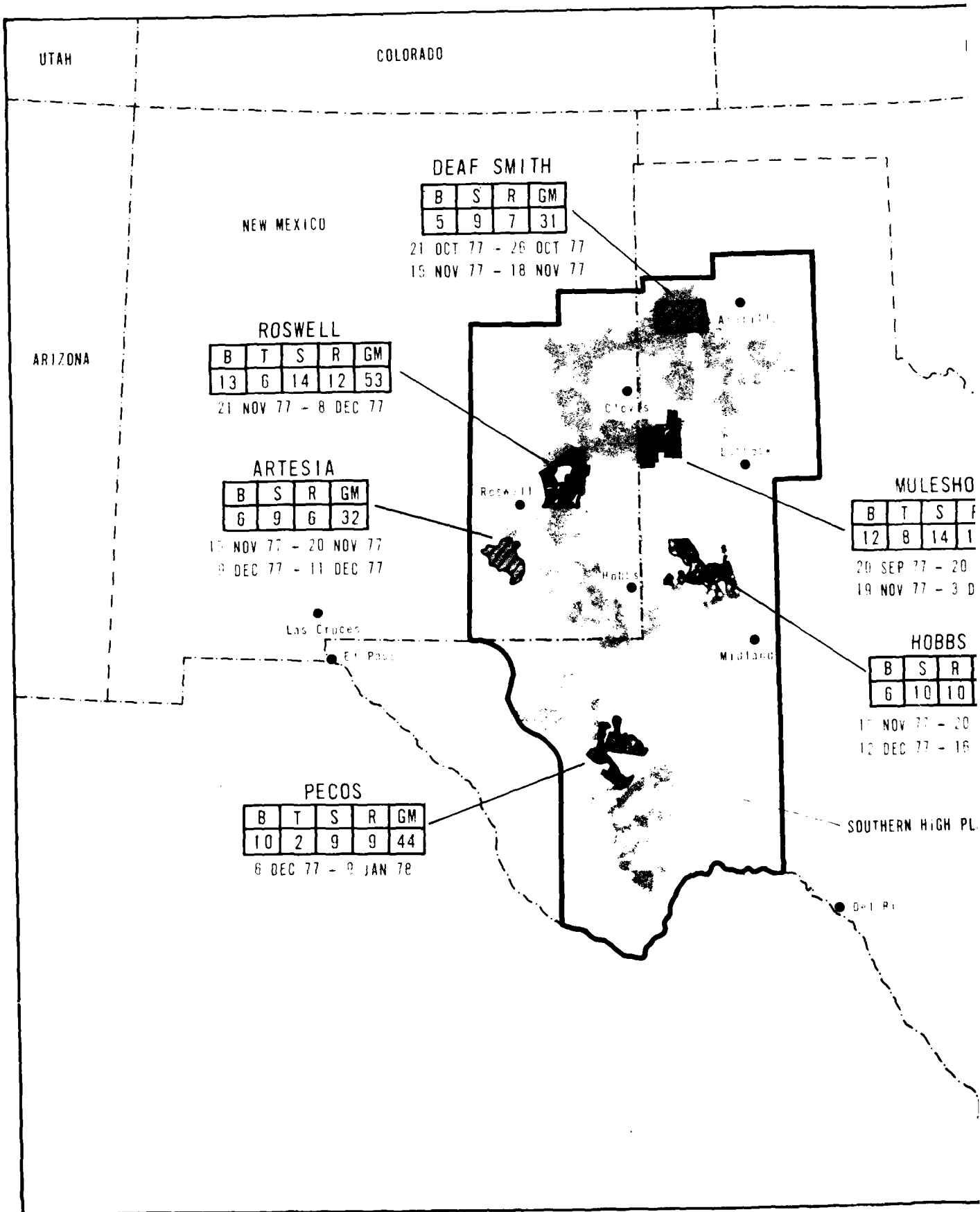
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1.0 INTRODUCTION

This report presents the results of geotechnical field investigations performed in the Muleshoe and Roswell characterization sites in west Texas and eastern New Mexico, respectively. Both sites are located in the Southern High Plains Candidate Siting Province (CSP), one of six provinces selected for the geotechnical Characterization studies. The location of the sites within the Southern High Plains CSP is shown in Figure 1 where the field activities are summarized. This report contains representative data collected and analyzed for these sites. Access to the remaining data can be arranged through SAMSO/MNND, Norton Air Force Base, California. The Southern High Plains CSP lies almost entirely within the Great Plains physiographic province and is characterized by flat-lying plains, rolling hills and valleys that are occasionally incised by stream channels.

Suitable area parcels remaining after Intermediate Screening were grouped into CSPs on the basis of similar geotechnical characteristics. The results of Intermediate Screening (FN-TR-17) indicated that existing data were not adequate in type or level of detail for follow-on geotechnical and geo-environmental evaluations, screening, site selection, and ranking studies. Therefore, the Characterization studies were developed to provide a rapid, relatively inexpensive method of gathering geotechnical data in small areas ($<700 \text{ nm}^2$; 2400 km^2) which are considered to be representative of a larger area within the CSP.



KANSAS

OKLAHOMA

MULESHOE

T	S	R	GM
8	14	14	67

EP 77 - 20 OCT 77
IOV 77 - 3 DEC 77

HOBBS

T	S	R	GM
3	5	10	43

IOV 77 - 20 NOV 77
DEC 77 - 18 DEC 77

SOUTHERN HIGH PLAINS

TEXAS

EXPLANATION

ACTIVITIES

- B - BORINGS
- T - TRENCHES
- S - SHALLOW SEISMIC REFRACTION LINES
- R - ELECTRICAL CONDUCTIVITY LINES
- GM - GEOLOGIC RECON MAPPING STATIONS

B	T
12	8

- Activity
- Quantity of each activity



SUITABLE AREA



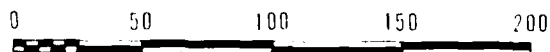
SUITABLE ROCK AREA



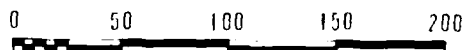
PRIME SITE



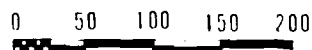
SUPPLEMENTAL SITE



NAUTICAL MILES



STATUTE MILES



KILOMETERS

CHARACTERIZATION SITES
AND FIELD ACTIVITIES
SOUTHERN HIGH PLAINS CSP

WET SITE INVESTIGATION
DEPARTMENT OF THE AIR FORCE

FIGURE

1

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Emphasis was placed on the collection of information allowing characterization of geologic units with respect to the construction aspects of MX missile basing mode options. Objectives of the Characterization studies were to obtain data that address the following geotechnical aspects:

- o Surficial geology and terrain
- o Subsurface conditions
- o Geophysical properties
- o Engineering properties

Although the program originally emphasized data collection for the trench and horizontal shelter basing modes, the data were utilized for evaluation of the vertical shelter basing mode as well. Characterization was, therefore, a refinement of the screening process whereby the necessary geotechnical information was developed to support the broader MX system design activities that were taking place concurrently and to provide a firmer basis from which to geotechnically rank the remaining suitable area, considering alternative basing modes.

Six Characterization sites (two prime and four supplemental) were selected in the Southern High Plains CSP (Figure 1), representing a total investigated area of less than ten percent of all suitable area within the CSP. Two sites which best represent the known geologic, geomorphic, and geo-environmental setting of the largest portion of the CSP are the Muleshoe and Roswell sites. The selection process began with a delineation of geotechnically similar areas within each CSP having analogous

depositional and geologic histories, rock and water depths, and tectonic settings. Once these areas had been identified, factors were applied to delineate the actual Characterization site boundaries. These non-geotechnical selection factors included access, proximity to support facilities, environmental sensitivities, and local logistical requirements.

Geologic, geophysical and soils engineering techniques were used to determine the surface and subsurface geotechnical conditions at the Muleshoe and Roswell sites. These included:

- o Analysis of available data
- o Delineation of surficial geologic units from soil groups mapped on U.S. Department of Agriculture and County Soil Survey aerial photographs
- o Geologic field check of aerial photo-interpretations and determination of physical properties of the surficial units at selected field stations
- o Shallow seismic refraction and electrical conductivity surveys to obtain subsurface profile
- o Drilling and trenching to determine subsurface characteristics and obtain soil samples
- o Laboratory testing of soil samples to determine engineering properties

Respective County offices for each site were contacted before initiation of field investigations in order to delineate buried utility lines and to obtain access permits. Prior to initiating any field work, an archeological and environmental inspection

was conducted at each site to ensure minimal impact to the local environment and to avoid damage to archeologic and historic sites. To further minimize potential impacts, all field activities were performed adjacent to existing roads or other previously disturbed areas.

2.0 MULESHOE SITE

The Muleshoe Characterization site covers an area of 450 nm² (1544 km²) in southern Bailey and northern Cochran counties, Texas. The site is bounded on the east by Lamb County and on the west by the New Mexico-Texas state line. Highway 298 forms most of the northern boundary and highway 125 bounds the southern extremity. Paved access within the site is provided by state highways 54, 596, 37, 213, and 116. Numerous unpaved county roads also aid travel within the area.

2.1 SCOPE OF INVESTIGATION

Geologic, geophysical and soils engineering field activities at the Muleshoe Site, as well as laboratory tests performed on soil samples from the site are presented in Table 1. Detailed information about the 12 borings and eight trenches is summarized in Tables 2 and 3. Figure 2 shows the location of field activities and their relation to the surficial geologic units. Appendix A presents a general explanation of the geologic units at the site.

2.2 SURFICIAL GEOLOGY AND TERRAIN

Eolian deposits which may be more than 100 feet (30 m) thick, cover 93 percent of the Muleshoe site (Figure 2 and Table 4). These deposits form a mantle of sheet sand (A3s) and dune sand (A3d) which overlies the Ogallala Formation. The eolian deposits are principally clayey and silty sands that have varying ~~degrees~~ ^{degrees} of caliche cementation. Approximately five percent of the A3s deposits contain moderately to strongly cemented caliche horizons which are a few inches to tens of feet thick.

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geological mapping stations	67
Shallow refraction	14
Resistivity	14

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
7	50 (15)
4	100 (30)
1	300 (91)
NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
3	12 (4)
4	7 (2)
1	3 (1)

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	90
Specific gravity	10
Sieve analysis	38
Hydrometer	32
Atterberg limits	32
Consolidation	3

TYPE OF TEST	NUMBER OF TESTS
Unconfined compression	3
Triaxial compression	6
Direct shear	6
Compaction	3
CBR	3
Chemical analysis	4

**SCOPE OF FIELD AND LABORATORY
ACTIVITIES
MULESHOE, TEXAS, SOUTHERN HIGH PLAINS CSP**

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
1

FUGRO NATIONAL, INC.

BORING NUMBER	TOTAL DEPTH FEET (METERS)	TYPE OF DRILL RIG USED	TYPE OF SAMPLES* OBTAINED
MS-B-1	101.0 (30.8)	Rotary Wash	D, P
MS-B-2	101.5 (30.9)	Rotary Wash	C, D, P
MS-B-3	50.0 (15.2)	Rotary Wash	D, P, C
MS-B-4	44.5 (13.6)	Rotary Wash	C, D
MS-B-5	300.0 (91.4)	Rotary Wash	C, D, P
MS-B-6	50.0 (15.2)	Rotary Wash	C, D, P
MS-B-7	101.0 (30.8)	Rotary Wash	P, C, D, SS
MS-B-8	51.2 (15.6)	Rotary Wash	D, P
MS-B-9	50.0 (15.2)	Rotary Wash	C, D, P
MS-B-10	50.0 (15.2)	Rotary Wash	C, D
MS-B-11	99.5 (30.3)	Rotary Wash	P, C, D
MS-B-12	50.0 (15.2)	Rotary Wash	C, D, P

*P = Pitcher sample (undisturbed)

D = Fugro Drive sample (relatively undisturbed)

SS = Split Spoon sample (undisturbed)

C = Rock Core

ENGINEERING FIELD ACTIVITIES - BORINGS
MULESHOE, TEXAS
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SANSO

TABLE
2

FUGRO NATIONAL, INC.

TRENCH NUMBER	TOTAL DEPTH FEET(METERS)	STABILITY OF VERTICAL EXCAVATION WALLS
MS-T-1	5.0 (1.5)	Stable, stage III caliche at 5.0' (1.5m) exceeded capacity of backhoe*
MS-T-2	12.0 (3.7)	Stable
MS-T-3	12.0 (3.7)	Unstable 0-10.0' (3.0m), sloughing into trench Stable 10.0-12.0' (3.0-3.7m)
MS-T-4	7.2 (2.2)	Stable, cementation at 7.2' (2.2m) exceeded capacity of backhoe*
MS-T-5	2.3 (0.7)	Stable, stage III caliche at 2.3' (0.7m) exceeded capacity of backhoe*
MS-T-6	7.0 (2.1)	Stable, stage III caliche at 7.0' (2.1m) exceeded capacity of backhoe*
MS-T-7	10.9 (3.3)	Stable
MS-T-8	6.7 (2.0)	Stable, stage III caliche at 6.7' (2.0m) exceeded capacity of backhoe*

*John Deere 400

ENGINEERING FIELD ACTIVITIES - TRENCHES
MULESHOE, TEXAS
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMS

TABLE
3

FUGRO NATIONAL, INC.

EXPLANATION

SURFICIAL GEOLOGIC UNITS

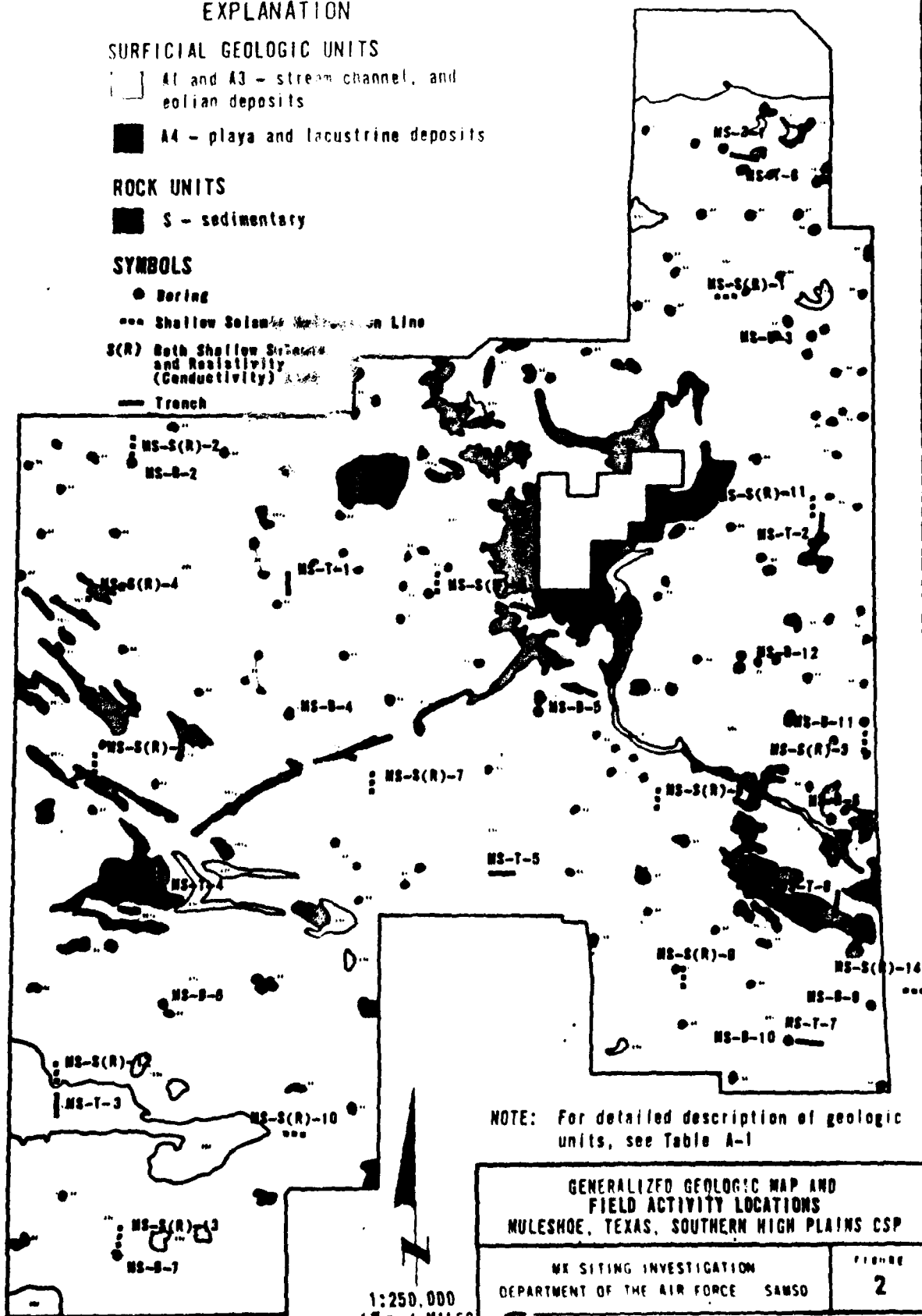
- A1 and A3 - stream channel, and eolian deposits
- A4 - playa and lacustrine deposits

ROCK UNITS

- S - sedimentary

SYMBOLS

- Boring
- Shallow Seismic Survey Line
- S(R) Both Shallow Seismic and Resistivity (Conductivity) Logs
- Trench



NOTE: For detailed description of geologic units, see Table A-1

GENERALIZED GEOLOGIC MAP AND
FIELD ACTIVITY LOCATIONS
MULESHOE, TEXAS, SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SANSO

FIGURE
2

FUGRO NATIONAL INC.

SURFICIAL GEOLOGIC UNIT (a)	GEOLOGIC AGE	THICKNESS FEET (METERS) (b)	DESCRIPTIVE NAME(S)	USCS SYMBOL(S) (c)	AREAL EXTENT (SITE)	
					nm ² (km ²)	PERCENT
Fluvial Deposits (A1)	Quaternary	10-30 (3-9)	Sandy Clay and Silty Sand	SM	5 (15)	1
Eolian Deposits, Dune Sand (A3d)	Quaternary	5-30 (1.5-9)	Silty Sand and Sand	SP	81 (277)	18
Eolian Deposits, Sheet Sand (A3s)	Quaternary	10-100 (3-31)	Sandy Clay and Clayey to Silty Sand	SC, SM	338 (1154)	75
Playa Deposits (A4)	Quaternary	10-20 (3-6)	Silty Clay Silty Sand	SM	18 (62)	4
Ogallala Formation (S5To)	Pliocene	50-100 (15-46)	Sandy Clay and Clayey to Silty Sand	CL, SC, SM	9 (31)	2

NOTES:

- (a) For generic description of geologic units, see Table A-1.
- (b) Thickness range represents the most common occurrence.
- (c) For description of USCS, see Table A-2.
- (d) For description of stage of caliche, see Figure A-1.
- (e) A3s deposits locally contain moderate to well-indurated caliche (five percent of site).
- (f) A well-indurated pisolitic and brecciated caliche caprock occurs extensively in the upper few feet of the formation.
- (g) Maximum grain size based on visual observations; engineering test data indicates larger particle sizes due to fragmentation of caliche.

EAL EXTENT (SITE)		PROPERTIES OF SURFACE MATERIALS					SURFACE MORPHOLOGY		NOTES
² (km ²)	PERCENT	GRADATION	CEMENTATION	MAXIMUM GRAIN SIZE	PAVEMENT/PATINA	STAGE OF CALICHE (d)	SLOPE (PERCENT)	DRAINAGE DEPTHS FEET (METERS)	
(15)	1	Poor	None	Sand	Not Applicable	None	1-3	10-20 (3-6)	
(277)	18	Poor	None-Weak	Sand	Not Applicable	None-I	5-40	None	
(1154)	75	Poor	Weak-Strong	Sand	Not Applicable	I-IV	0-8	10-20 (3-6)	(e) (g)
(62)	4	Poor	None-Weak	Sand	Not Applicable	None-I	0-3	15-30 (5-9)	
(31)	2	Poor	Weak-Very Strong	Gravel	Not Applicable	I-IV	0-3	10-20 (3-6)	(f) (g)

DESCRIPTION OF SURFICIAL GEOLOGIC UNITS	
MULESHOE, TEXAS SOUTHERN HIGH PLAINS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE	SAMSO TABLE 4
FUGRO NATIONAL, INC.	

2

Other surficial units include fluvial (A1) and playa and lacustrine deposits (A4) which together comprise five percent of the Muleshoe site. These deposits consist of mixtures of sand, silt, and clay and range in thickness from ten to 30 feet (3 to 9 m). The Ogallala Formation is exposed over only two percent of the site.

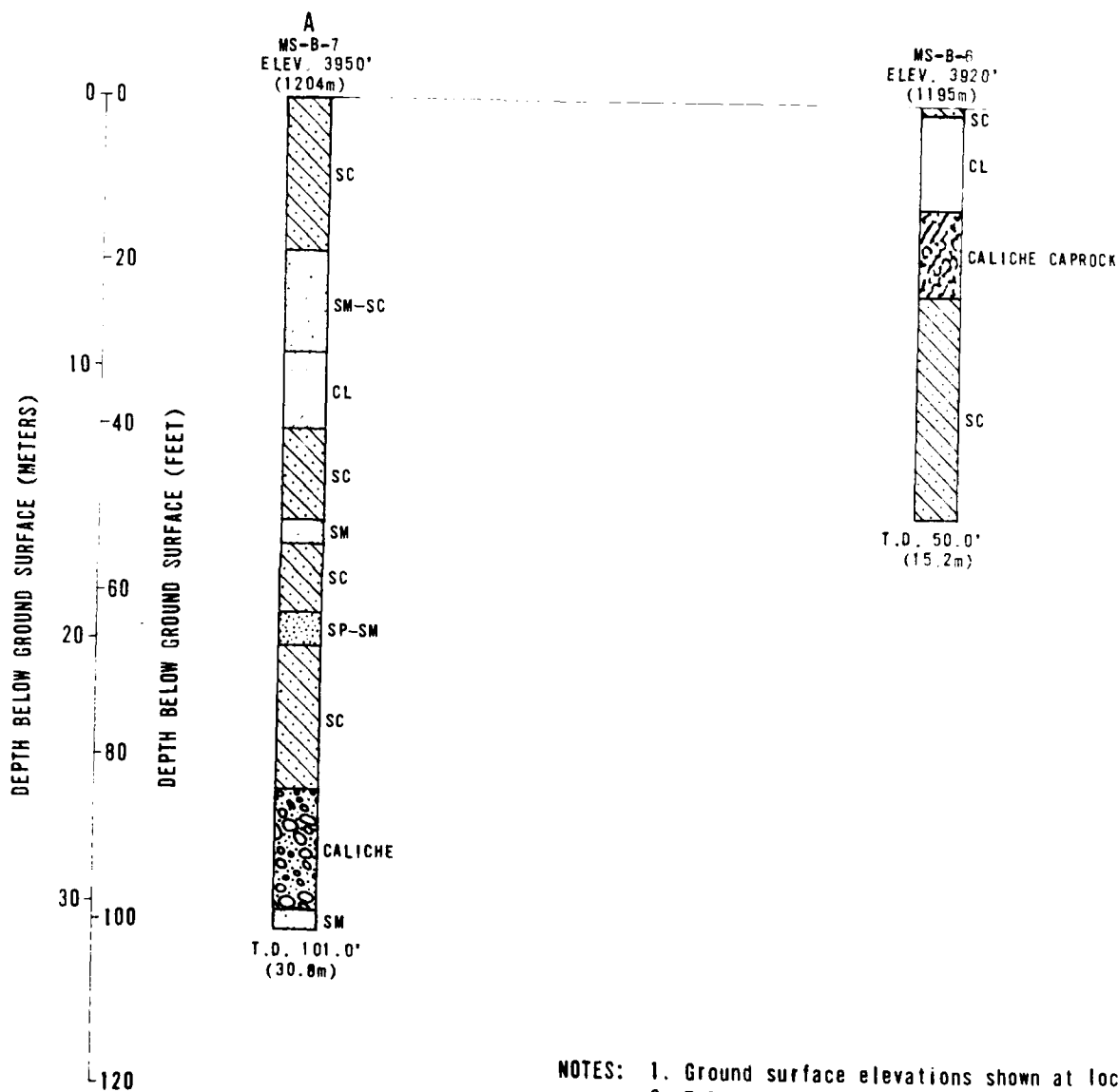
The Muleshoe site is a broad, nearly featureless plain incised by widely spaced streams along the margins and dotted by numerous small natural depressions or playas. Surface slopes are generally less than three percent, except in dune areas. Stream incisions and playas are less than 30 feet (9 m) deep, are relatively broad, and have subtle banks.

2.3 SUBSURFACE CONDITIONS

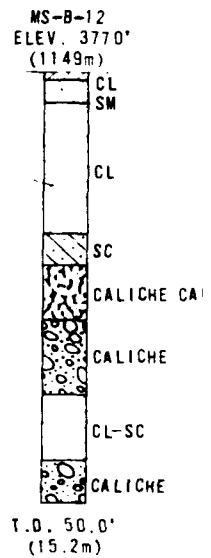
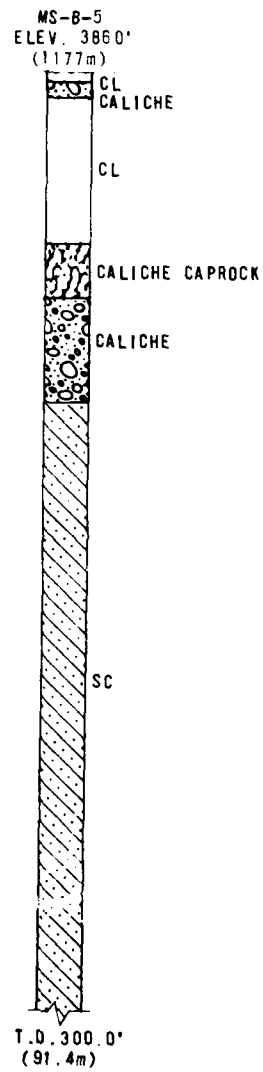
2.3.1 Subsurface Profile

The soils encountered in the subsurface are illustrated in Figures 3 and 4. The Pliocene Ogallala Formation underlies all of the Muleshoe site ranging in thickness from 50 to 100 feet (15 to 30 m). It is composed of beds and lenses of calcareous clay, silt, sand, gravel, and caliche. The most important lithologic feature of the Ogallala Formation is the caprock, a well indurated, massive caliche which is pisolitic, brecciated, and silicified in part. The caprock ranges in thickness from a few inches to tens of feet and forms a prominent escarpment around the entire physiographic section.

Underlying the Ogallala Formation (Figures 3, 4 and 5) are the Triassic Dockum Group (sandstone, siltstone and gypsum) and



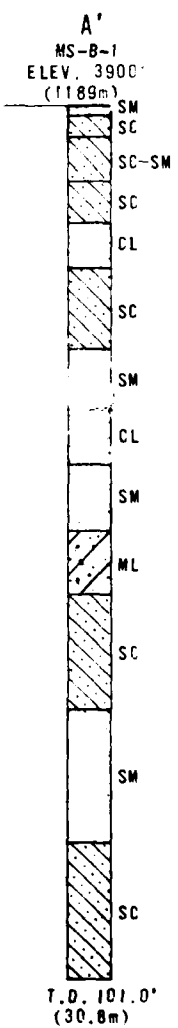
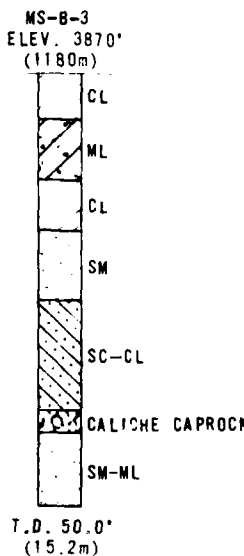
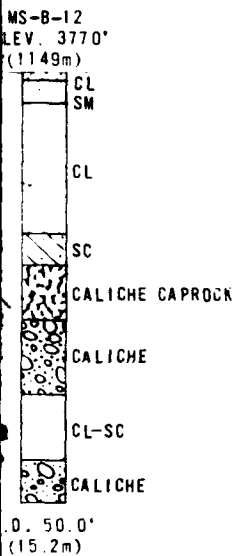
- NOTES:
1. Ground surface elevations shown at locations of bo
 2. T.D.=Total Depth
 3. Soil types shown adjacent to soil column are based (USCS) and are explained in the appendix



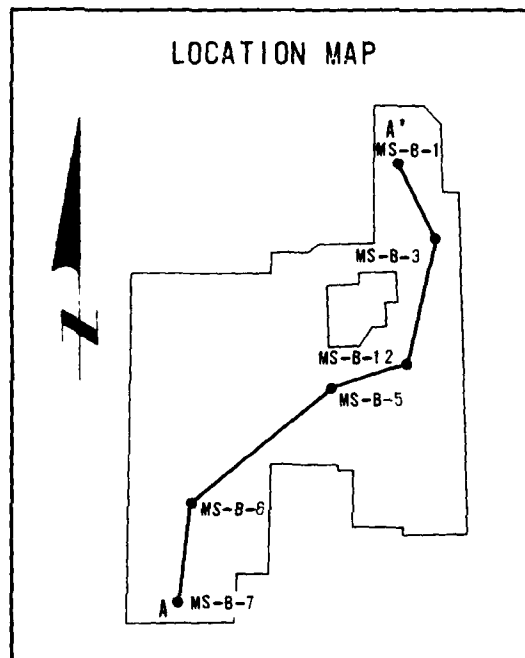
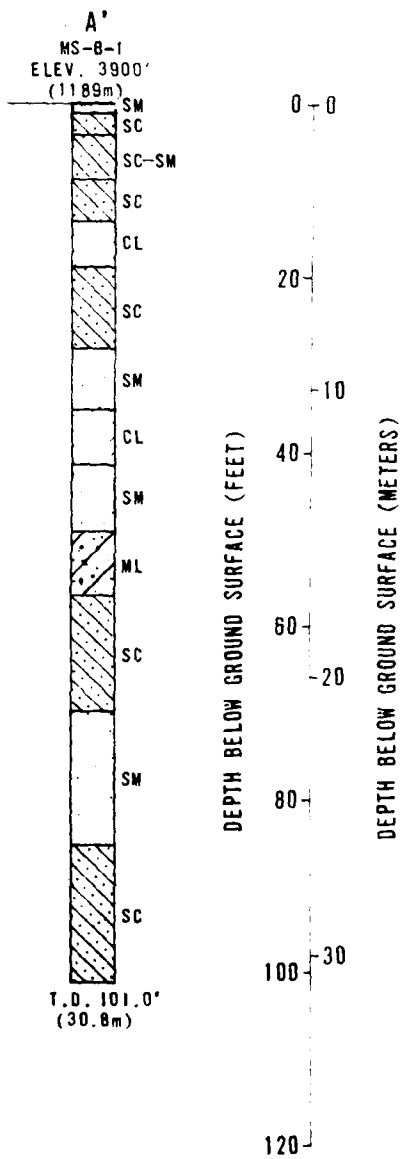
ons of borings are approximate
are based on Unified Soil Classification System

STATUTE
KILOM

2-



3

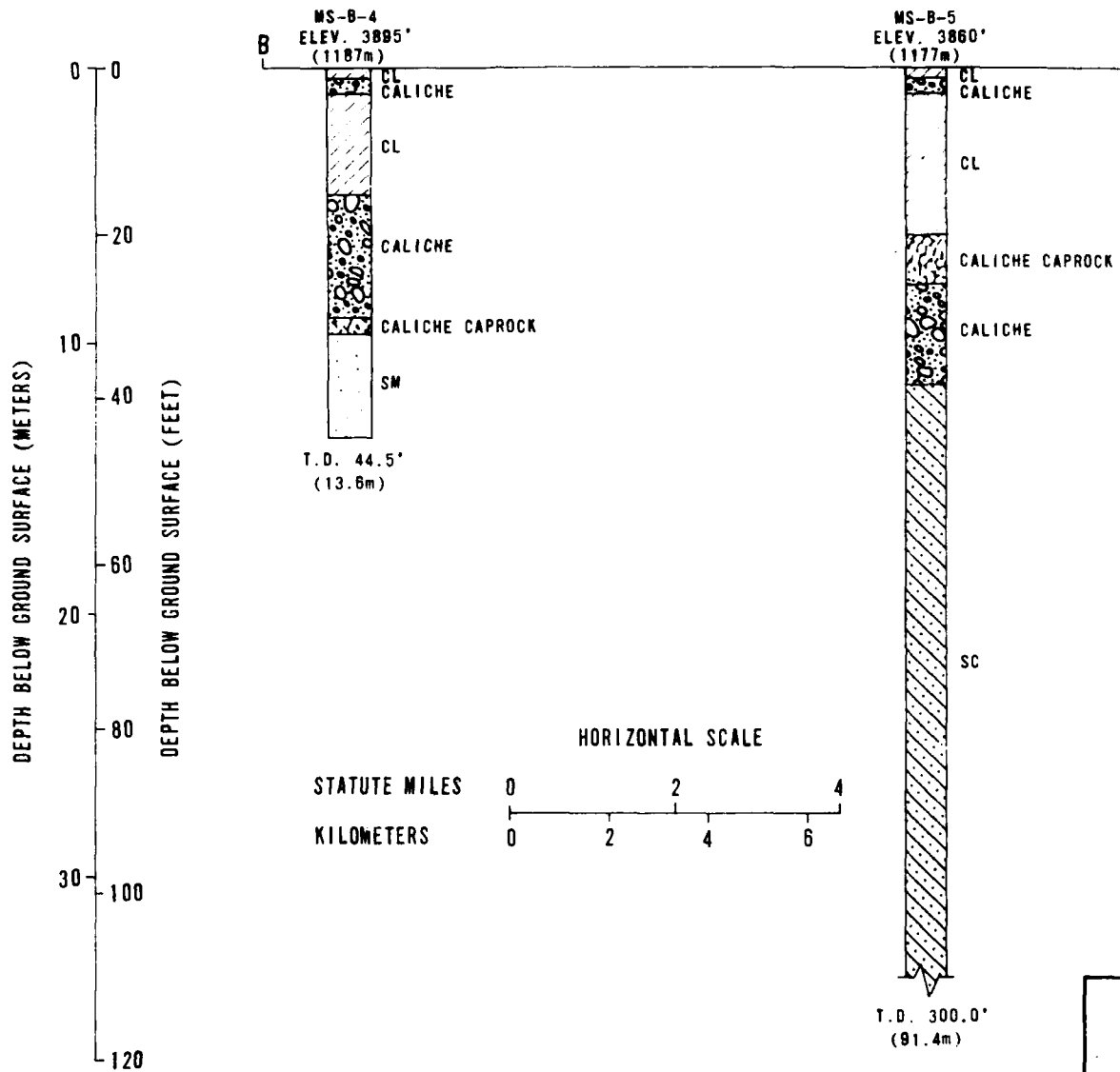


SOIL PROFILE AA'
MULESHOE, TEXAS
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSQ

FIGURE
3

FUGRO NATIONAL INC.



- NOTES:
1. Ground surface elevations shown at locations of borings are approximate
 2. T.D. Total Depth
 3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix



MS-B-11
ELEV. 3730'
(1137m)

B'

SM

CL

CALICHE CAPROCK

CALICHE

CL

SM-ML

CH

DEPTH BELOW GROUND SURFACE (FEET)

DEPTH BELOW GROUND SURFACE (METERS)

T.D. 99.5'
(30.3m)

LOCATION MAP

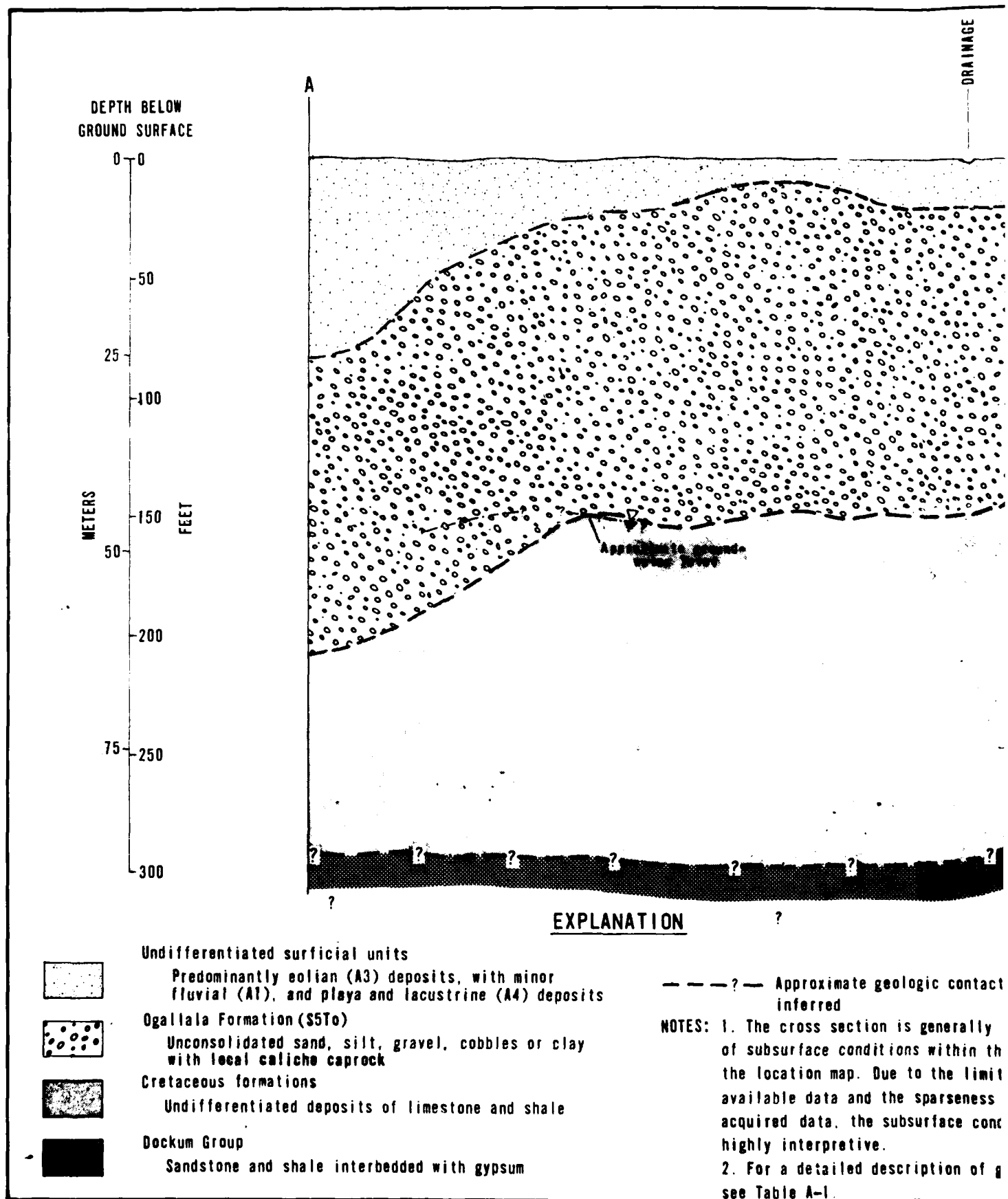
MS-B-4 MS-B-5 MS-B-11 B'

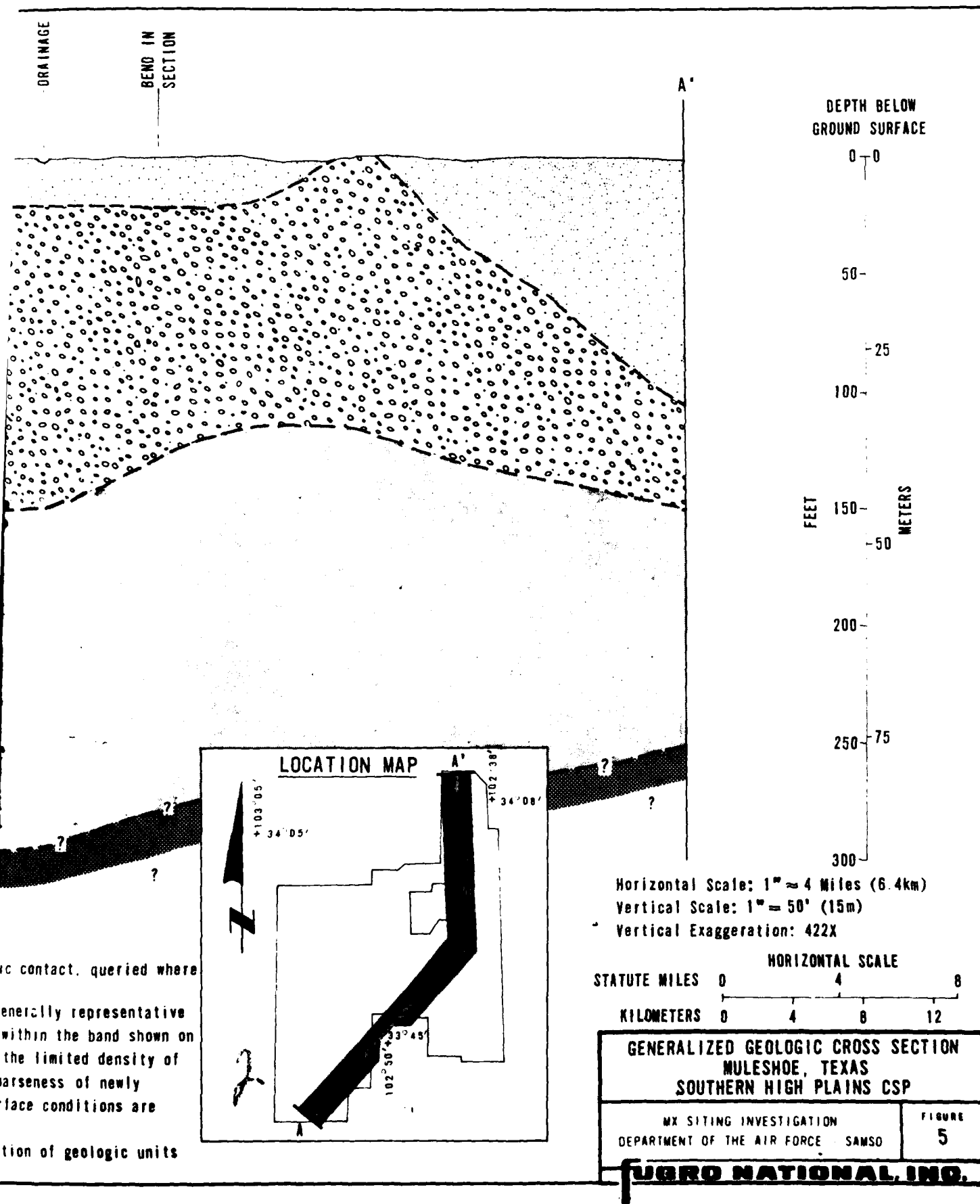
SOIL PROFILE BB'
MULESHOE, TEXAS
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
4

FURRO NATIONAL, INC.





several Cretaceous formations (shale and limestone). The entire site is underlain by these excavatable rock units generally at depths less than 150 feet (46 m).

2.3.2 Depth to Shallow (<150 feet; 46 m) Rock and Water

According to available regional data, non-excavatable rock does not occur anywhere in the site at depths less than 150 feet (46 m). Bedrock velocities (>7000 fps; 2134 mps) were encountered within the construction zone but are expected to represent thin layers of cemented caliche that will be excavatable.

Ground water occurs at depths exceeding 100 feet (30 m) in 75 percent of the site. Field investigations and published data indicate that the ground water is shallower than 150 feet (46 m) over most of the site, with the exception of the extreme southern tip (Figure 6).

2.4 GEOPHYSICAL PROPERTIES

Results of the shallow seismic and conductivity surveys are presented in Table 5 and 6, respectively. Observed seismic velocities ranged from 1560 to 9980 fps (475 to 3042 mps). The surface layer is generally about ten feet (3 m) thick and has a velocity between 1560 and 2550 fps (475 to 777 mps). "Bedrock" velocities (>7000 fps; 2134 mps) are observed at 64 percent of the seismic line locations at depths between zero and 35 feet (11 m). These bedrock velocities were associated with thin layers of caliche. Layers with velocities between 6000 and 7000 fps (1829 and 2134 mps) were observed at 21 percent of the seismic line locations, they were also associated with caliche

EXPLANATION

SURFICIAL GEOLOGIC UNITS

□ A1 and A3 - fluvial and eolian deposits

■ A4 - playa and lacustrine deposits

■ S5To - Ogallala Formation

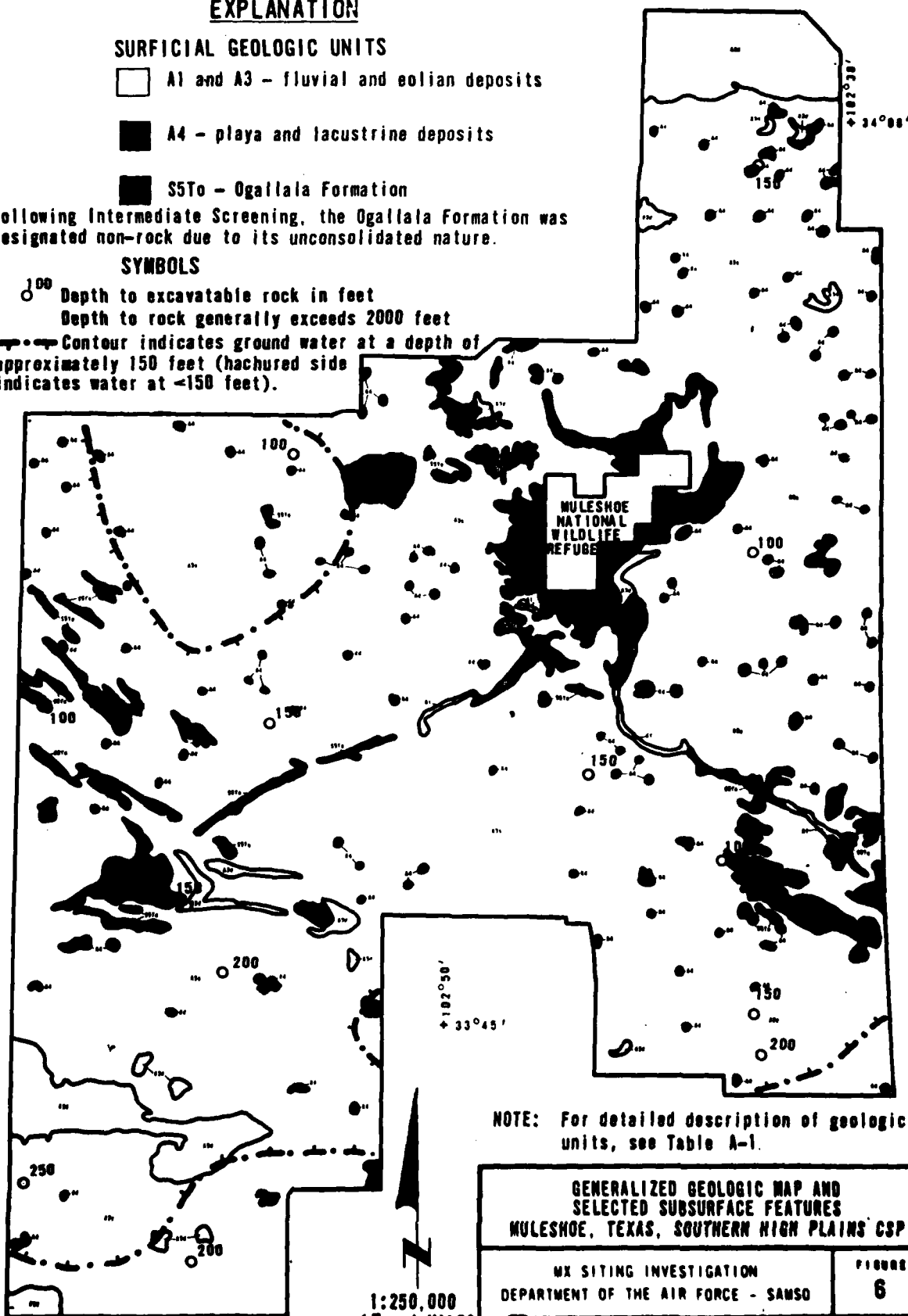
Following Intermediate Screening, the Ogallala Formation was designated non-rock due to its unconsolidated nature.

SYMBOLS

○ 100 Depth to excavatable rock in feet

Depth to rock generally exceeds 2000 feet

--- Contour indicates ground water at a depth of approximately 150 feet (hachured side indicates water at <150 feet).



NOTE: For detailed description of geologic units, see Table A-1.

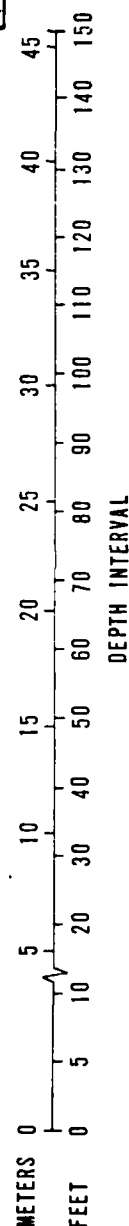
GENERALIZED GEOLOGIC MAP AND
SELECTED SUBSURFACE FEATURES
MULESHOE, TEXAS, SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANSO

FIGURE
6

FUGRO NATIONAL INC.

SEISMIC LINE NO.	VELOCITY DISTRIBUTION FPS (MPS)				DEEPER REFRACTORS		* ROCK EXCLUSION DEPTH TO 7000 FPS (2134 MPS)
					DEPTH	VELOCITY	
MS-S-1	2000 (610)	3500 (1070)	4400 (1340)	▲	-	-	130 (40)
MS-S-2	1560 (480)	3030 (920)	7160 (2180)	▲	-	-	-
MS-S-3	1850 (560)	▲	9150 (2790)	▲	-	-	-
MS-S-4	▲	7000 (2130)	▲	▲	-	-	-
MS-S-5	2350 (720)	▲	6350 (1940)	▲	-	-	35 (11)
MS-S-6	▲	7200 (2190)	▲	▲	-	-	-
MS-S-7	2100 (640)	▲	9980 (3040)	▲	-	-	-
MS-S-8	2550 (780)	▲	8280 (2520)	▲	-	-	-
MS-S-9	2450 (750)	▲	9100 (2770)	▲	-	-	-
MS-S-10	2300 (700)	▲	6480 (1980)	▲	-	-	40 (12)
MS-S-11	1880 (570)	▲	8300 (2530)	▲	-	-	-
MS-S-12	2050 (620)	▲	6100 (1860)	▲	-	-	80 (24)
MS-S-13	1650 (500)	2660 (810)	4720 (1440)	▲	-	-	128 (39)
MS-S-14	2050 (620)	▲	7900 (2410)	▲	-	-	-



• If no refracting interface or layer with a velocity greater than 7000 fps (rock/rock-like material) was detected, a rock exclusion depth calculation was performed to determine the minimum depth at which rock could occur.

SHALLOW SEISMIC REFRACTION RESULTS
MULESHOE, TEXAS
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
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TABLE
5

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ACTIVITY LOCATION*	AVERAGE CONDUCTIVITY (mhos m)**
R-1	.044
R-2	.021
R-3	.023
R-4	.0026
R-5	.031
R-6	.0035
R-7	.010
R-8	.013
R-9	.024
R-10	.015
R-11	.038
R-12	.013
R-13	.030
R-14	.032

*Resistivity was determined using a Schlumberger Array at each location where a seismic refraction survey was conducted.

**Conductivity is the inverse of resistivity. Numbers presented are the average of values determined to a depth of 50 feet, computed as follows:

$$\text{Average Conductivity} = (C_1 t_1 + C_2 t_2 + \dots + C_n t_n) / 50 \text{ feet}$$

Where

Average Conductivity = mhos/m

C_1 through C_n = Conductivity (mhos/m) of layers 1 through n

t_1 through t_n = Thickness (feet) of layers 1 through n to 50 feet

CONDUCTIVITY SURVEY RESULTS
MULESHOE, TEXAS
SOUTHERN HIGH PLAINS CSP

VI SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSC

TABLE

6

FUGRO NATIONAL, INC.

stringers. Low velocity layers below the caliche cannot be detected by refraction; consequently the velocity distribution table probably does not accurately describe the velocity below the interface with the high velocity (>6000 fps; 1829 mps) layer.

Average conductivities for the upper 50 feet (15 m) of the subsurface ranged from 0.0026 to 0.044 mhos/m. Two of the 14 conductivity measurements were below the minimum of 0.004 mhos/m specified in the Fine Screening criteria. These occurred at the two locations where "bedrock" velocities were observed at the surface.

2.5 ENGINEERING PROPERTIES

Laboratory tests were performed to determine the engineering properties of soils obtained from the various geologic units. The testing program consisted of classification, consolidation, shear strength, compaction, CBR, and chemical tests. The range of engineering and geophysical properties of the predominant geologic units is presented in Table 7 and Figure 7. Sheet and dune sand deposits have been combined into a single category, eolian deposits, due to their similar characteristics. The properties of caliche encountered at the site are generally not included in Table 7 and Figure 7 due to insufficient data. Both the eolian deposits and the Ogallala Formation consist mainly of sandy clay and clayey to silty sand which are generally cemented. These units are moderately compressible and have moderate shear strengths. The site soils generally are neither

ENGINEERING AND GEOPHYSICAL PROPERTIES*		
	Eolian sand deposits (A3s and A3d)	Ogallala formation
UNIFIED SOIL CLASSIFICATION SYMBOL(S)	CL, SC, SM	CL, SC, SM, OH
GENERAL PROPERTIES		
DRY DENSITY pcf(kg m ³)	90-120 (1442-1922)	95-125 (1522-2000)
MOISTURE CONTENT (%)	5-20	5-25
DEGREE OF SATURATION (%)	30-100	30-100
SPECIFIC GRAVITY	2.6-2.7	2.6-2.7
DEGREE OF CEMENTATION	Weak to strong	Weak to very strong
COMPRESSIONAL WAVE VELOCITIES fps(mps)	1560-2550 (475-777)	2700-10,000 (823-3048)
ELECTRICAL CONDUCTIVITY (mhos m)	003-044	001-031
GRAIN SIZE DISTRIBUTION (%)		
BOULDERS >12 inches(30cm)	0	0
COBBLES 3 to 12 inches (8 to 30cm)	0-5	0-30
GRAVEL	0-28	0-43
SAND	16-76	0-90
SILT AND CLAY	24-57	10-75
PLASTICITY DATA		
LIQUID LIMIT	NP-35	NP-45
PLASTICITY INDEX	NP-15	NP-20
COMPRESSIBILITY DATA		
COMPRESSION AT 4 ksf(192kN/m ²) (%)	1-2	1±
SWELL OR COLLAPSE UPON SATURATION (%)	0-0.5 (Swell)	0.1± (Swell)
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION ksf(kN/m ²)	0.2-1 (10-48)	2± (96±)
CD TRIAXIAL COMPRESSION	c = 0.5-1.5 ksf (24-72 kN m ²), $\phi = 25^\circ-35^\circ$	c = 0.5-1.5 ksf (24-72 kN m ²)
DIRECT SHEAR ksf(kN m ²)	1-5 (48-239)	4± (192±)
COMPACTION AND CBR DATA		
MAXIMUM DRY DENSITY pcf(kg m ³)	115-125 (1842-2002)	115-125 (1842-2000)
OPTIMUM MOISTURE CONTENT (%)	10-15	10-15
CBR AT 90% RELATIVE COMPACTION	40	5-40

DNA = DATA NOT AVAILABLE (INSUFFICIENT DATA OR TESTS NOT PERFORMED).

*PROPERTIES OF CALICHE GENERALLY NOT INCLUDED AS DATA IS INSUFFICIENT. DIFFERENT DEGREES OF CALICHE DEVELOPMENT IN EOLIAN DEPOSITS AND OGALLALA FORMATION AFFECTS ENGINEERING CHARACTERISTICS.

GEOLOGIC UNITS

allala formation (S5To)

CL, SC, SM, GM

95-125 (1522-2002)

5-25

10-100

2 6-2 7

Weak to very strong

700-10,000 (823-3048)

001- 031

0

0-30

0-43

0-90

10-75

NP-45

NP-20

1±

0.1± (Swell)

2± (96±)

5 ksf (24-72 kN m²), $\phi = 25^\circ - 35^\circ$

4± (192±)

115-125 (1842-2002)

10-15

5-40

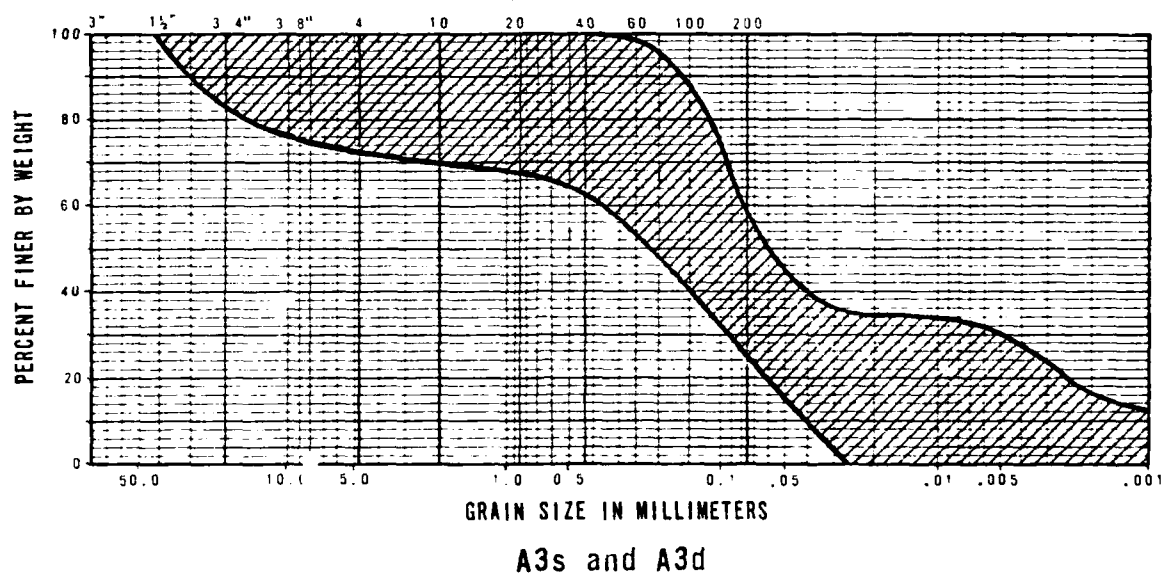
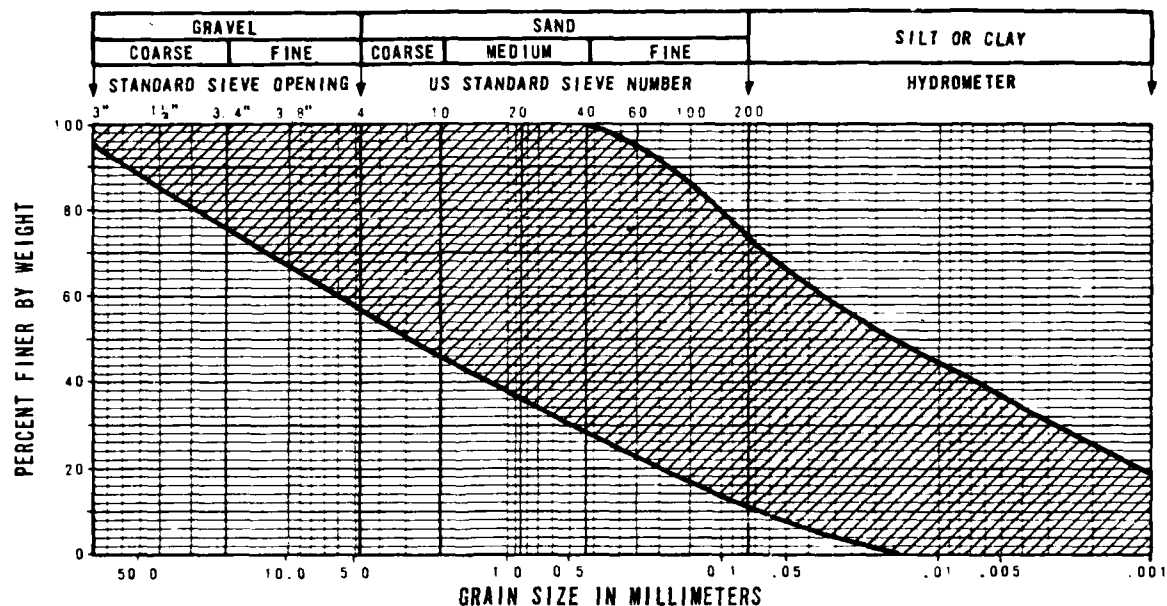
RANGE OF ENGINEERING AND
GEOPHYSICAL PROPERTIES
MULESHOE, TEXAS, SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSQ

TABLE

7

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RANGE OF GRADATION OF GEOLOGIC UNITS
MULESHOE, TEXAS
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE DAWSO

FIGURE
7

FUGRO NATIONAL, INC.

expansive nor collapsible. The presence of chalky to strongly cemented caliche in these units affects their engineering characteristics.

Representative logs of three borings and three trenches from the site are contained in Appendix B. Results of the shear strength, CBR and chemical tests performed on samples from the site and a summary of all the laboratory tests performed on soil samples obtained from Boring MS-B-1 are also included in Appendix B.

3.0 ROSWELL SITE

The Roswell Characterization site covers an area of 540 nm² (1852 km²) in eastern Chaves County, New Mexico. The site is bounded by Roosevelt and Lea Counties in the east, and an 18 nm exclusion boundary from Roswell, New Mexico, in the west. U.S. Highway 70 forms the northern edge of the site, and latitude 33° 15' runs adjacent to the southern boundary. Most roads within the site are unpaved and provide access to a large oil exclusion area in the center of the site. U.S. Highway 380 and State Highway 172 provide the main paved access in the southern portion of the site.

3.1 SCOPE OF INVESTIGATION

Geologic, geophysical, and soil engineering field activities at the Roswell site, as well as laboratory test performed on soil samples from the site are presented in Table 8. Information about the 13 borings and six trenches is summarized in Tables 9 and 10. Figure 8 shows the location of field activities and their relation to the surficial geologic units.

3.2 SURFICIAL GEOLOGY AND TERRAIN

Wind-blown (eolian) deposits are the predominant surficial geologic units within the Roswell Characterization site (Figure 8). Dune sands cover approximately 40 percent of the area, primarily in the east and southwest portions of the area. Sheet sands cover an estimated 39 percent of the site. Terrace deposits are mapped over about 15 percent of the surface and can be expected to underlie 90 percent of the other surficially mapped units.

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	53
Shallow refraction	14
Resistivity	12

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
8	50 (15)
1	82 (25)
3	100 (30)
1	300 (91)
NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
4	12 (4)
1	8 (2)
1	2 (1)

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture density	130
Sieve analysis	28
Hydrometer	29
Atterberg limits	27
Specific gravity	10
Consolidation	3

TYPE OF TEST	NUMBER OF TESTS
Unconfined compression	6
Triaxial compression	6
Direct shear	6
CBR	2
Compaction	3
Chemical analysis	5

SCOPE OF FIELD AND LABORATORY
ACTIVITIES
ROSWELL, NEW MEXICO, SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSC

TABLE
8

FUGRO NATIONAL, INC.

BORING NUMBER	TOTAL DEPTH FEET (METERS)	TYPE OF DRILL RIG USED	TYPE OF SAMPLES* OBTAINED
RL-B-1	50.0 (15.2)	Rotary Wash	P, D, C
RL-B-2	52.5 (16.0)	Rotary Wash	P, D, C
RL-B-3	101.0 (30.8)	Rotary Wash	P, D
RL-B-4	51.0 (15.5)	Rotary Wash	P, D
RL-B-5	82.5 (25.1)	Rotary Wash	C, P, D
RL-B-6	50.4 (15.4)	Rotary Wash	P, D
RL-B-7	50.6 (15.4)	Rotary Wash	P, D
RL-B-8	51.2 (15.6)	Rotary Wash	P, D, C
RL-B-9	101.0 (30.8)	Rotary Wash	P, D
RL-B-10	302.5 (92.2)	Rotary Wash	P, D
RL-B-11	50.0 (15.2)	Rotary Wash	P, D, C
RL-B-12	100.6 (30.7)	Rotary Wash	P, D, C
RL-B-13	51.6 (15.7)	Rotary Wash	P, D

*P = Pitcher sample (undisturbed)

D = Fugro Drive sample (relatively undisturbed)

C = Rock Core

ENGINEERING FIELD ACTIVITIES - BORINGS
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE

9

FUGRO NATIONAL, INC.

TRENCH NUMBER	TOTAL DEPTH FEET(METERS)	STABILITY OF VERTICAL EXCAVATION WALLS
RL-T-1	8.1 (2.5)	Stable, stage <u>III</u> caliche at 8.1' (2.5m) exceeded capacity of backhoe*
RL-T-2	13.0 (4.0)	Stable
RL-T-3	12.4 (3.8)	Stable
RL-T-4	12.1 (3.7)	Stable
RL-T-5	13.0 (4.0)	Stable
RL-T-6	1.5 (0.5)	Stable, stage <u>IV</u> caliche at 1.5' (0.5m) exceeded capacity of backhoe*

*Case 580

ENGINEERING FIELD ACTIVITIES - TRENCHES
 ROSWELL, NEW MEXICO
 SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMSQ

TABLE
 10

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Other non-rock units including fluvial, playa and lacustrine, and alluvial fan deposits make up a total of less than five percent. *Excavatable rock ~~units~~ consist of the Ogallala Formation which outcrops along the eastern site boundary, and the Dockum Group which is not expressed surficially but which probably underlies most of the site at a depth of less than 50 feet

(15 m).

*The Ogallala Formation is considered to be a non-rock unit, but it locally contains well-indurated caliche caprock.

Eolian dune and sheet sand deposits are commonly composed of sand or silty sand. They may be underlain by soft caliche at depths of two to four (0.6 to 1.2 m) feet.

Terrace deposits are composed primarily of beds of silt and sand. Approximately 50 percent of these terrace units, and five percent of the sheet sands are underlain by hard, resistant layers of caliche at a depth of less than five feet (1.5 m).

All the surficial geologic units within the site are described in Table 11.

The Roswell site is a broad, gently undulating plain with poorly developed drainage. Surface slopes range from zero to three percent in terrace and sheet sand deposits, and zero to 30 percent in dune areas. Streams are irregularly spaced many miles apart across much of the site, and are essentially non-existent in areas occupied by dune sands. Stream channels are broad and shallow with a depth of incision rarely exceeding ten feet (3 m).

Two extensive linear dikes composed of gabbro, strike roughly east-west across the site. One of these, the Railroad Mountain

SURFICIAL GEOLOGIC UNIT (a)	GEOLOGIC AGE	THICKNESS FEET (METERS) (b)	DESCRIPTIVE NAME(S)	USCS SYMBOL(S) (c)	AREAL EXTENT (SITE)	
					nm ² (km ²)	PERCENT
Stream Channel and Alluvial Outwash Deposits (A1/A1W)	Holocene	0-20 (0-6)	Silty Clay Clayey Silt and Silty Sand	CL, ML, SM	11 (38)	2
Terrace Deposits (A2)	Pliocene-Holocene	5-10 (2-3)	Silty Gravel to Clayey Silt	SM, GM	81 (278)	15
Eolian Deposits (A3)	Holocene	0-60 (0-18)	Sand and Silty Sand	SP, SM	427 (1 465)	79
Lacustrine and Playa Deposits (A4)	Holocene	0-20 (0-6)	Silty Sand to Silty Clay	SM	5 (17)	1
Alluvial Fan Deposits (A5)	Holocene	0-20 (0-6)	Silty Sand	SM	5 (17)	1
Igneous Rock-Dikes (I2)	Oligocene	50-100 (15-30)	Olivine Gabbro	—	11 (38)	2

NOTES:

- (a) For generic description of geologic units, see Table A-1.
- (b) Thickness range represents the most common occurrence.
- (c) For description of USCS, see Table A-2.
- (d) For description of stage of caliche, see Figure A-1.
- (e) Approximately 30 percent of these deposits are underlain by resistant layers of caliche.
- (f) Approximately 50 percent of these deposits are underlain by resistant layers of caliche.

*I.D. — Insufficient Data

TENT (SITE)		PROPERTIES OF SURFACE MATERIALS				SURFACE MORPHOLOGY		NOTES
PERCENT	GRADATION	CEMENTATION	MAXIMUM GRAIN SIZE	PAVEMENT/PATINA	STAGE OF CALICHE (d)	SLOPE (PERCENT)	DRAINAGE DEPTHS FEET (METERS)	
2	Poor	None-Strong	Sand	Not Applicable	None-I	0-5	0-9 (0-3)	
15	Poor	None-Strong	Cobble	Not Applicable	None-IV	0-3	1.0 *	(e)
79	Poor	None-Strong	Sand	Not Applicable	None-IV	0-30	1.0	(f)
1	Poor	None-Weak	Sand	Not Applicable	None-I	0-3	1.0	
1	Poor	None-Weak	Cobble	Not Applicable	None-I	0-9	1.0.	
2	—	—	—	Not Applicable	Not Applicable	Not Applicable	1.0.	

2

DESCRIPTION OF SURFICIAL
GEOLOGIC UNITS
ROSWELL, NEW MEXICO, SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
11

FUGRO NATIONAL, INC.

dike, is more than 30 miles (48 km) long, and 100 feet (30 m) wide. It is resistant to erosion and poses a formidable barrier to excavation. The other dike, El Camino Diablo, is approximately 50 feet (15 m) wide and ten miles (16 km) long. It is highly decomposed near the surface, and is generally covered by eolian deposits.

3.3 SUBSURFACE CONDITIONS

3.3.1 Subsurface Profile

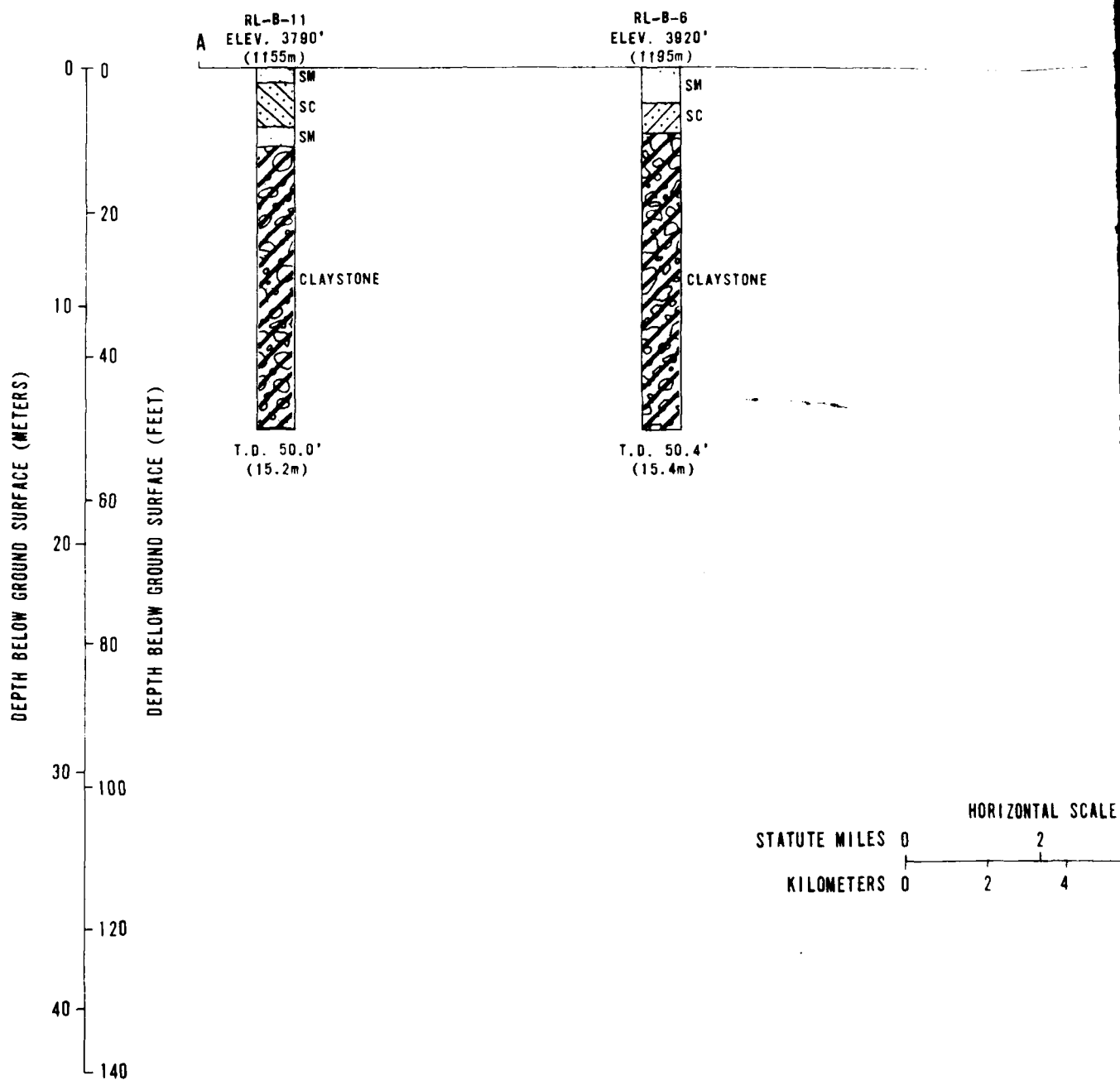
The subsurface soils encountered at the Roswell site are illustrated in Figures 9 and 10. The predominant surficial soils are silty and clayey sands and their cementation varies from none to strong. They are underlain by the Triassic Dockum group over most of the site (Figure 11). This formation is composed of sandstone, claystone, and gypsum.

3.3.2 Depth to Shallow (150 ft; 46 m) Rock and Water

Figure 12 shows portions of the site in which water is estimated to be encountered within a depth of 150 feet (46 m) below the ground surface. Based on available regional data, approximately three percent of the site is underlain by shallow water. Non-excavatable rock at less than 150 feet (46 m) of depth is only encountered immediately adjacent to the Railroad Mountain and El Camino Diablo dikes.

3.4 GEOPHYSICAL PROPERTIES

Results of the shallow seismic and conductivity surveys are presented in Tables 12 and 13, respectively. Observed seismic velocities ranged from 1100 to 11,450 fps (335 to 3490 mps).



- NOTES:
1. Ground surface elevations shown at locations of borings are approximate
 2. T.D. Total Depth
 3. Soil types shown adjacent to soil column are based on Unified Soil Classification (USCS) and are explained in the appendix

RL-B-10
ELEV. 4040'
(1231m)



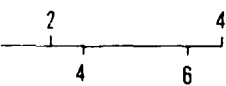
T.D. 302.5'
(92.2m)

RL-B-2
ELEV. 4210'
(1283m)



T.D. 52.5'
(16.0m)

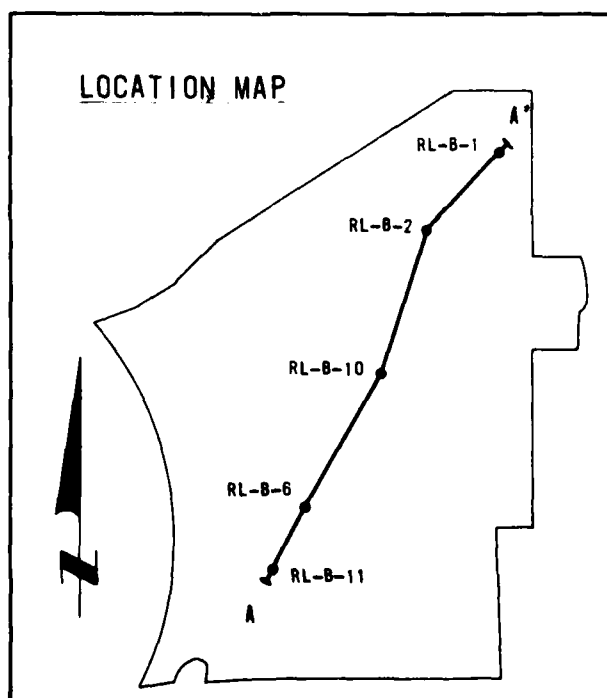
HORIZONTAL SCALE

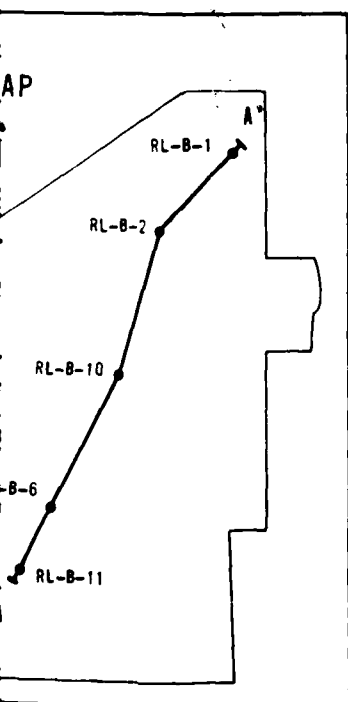
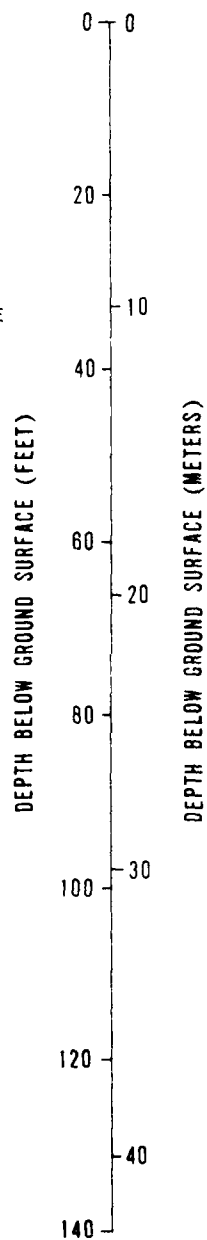
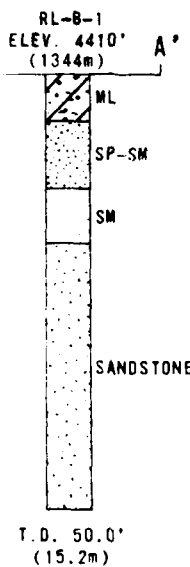
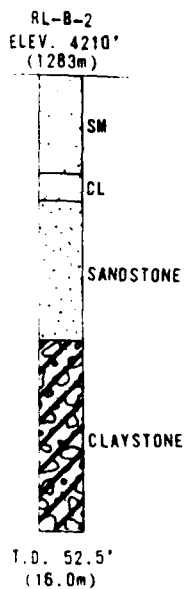


te
Classification System

2

LOCATION MAP



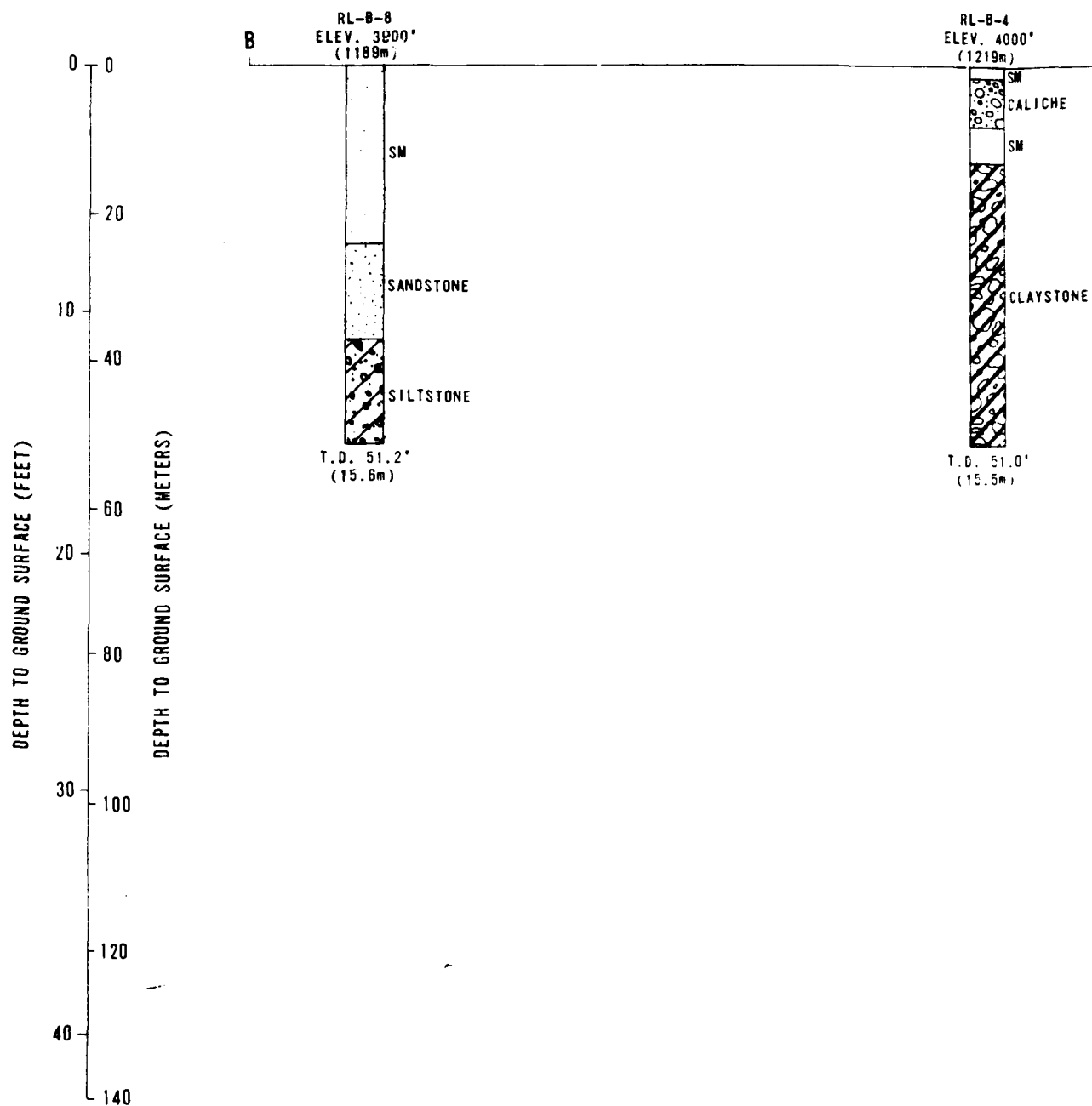


SOIL PROFILE AA'
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SANSO

FIGURE
9

FURRO NATIONAL, INC.



- NOTES: 1. Ground surface elevations shown at locations of borings are
 2. T.D. Total Depth
 3. Soil types shown adjacent to soil column are based on Unified (USCS) and are explained in the appendix

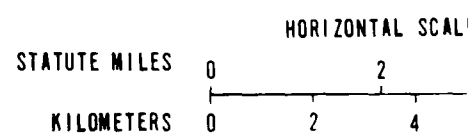
-4
4000'
(m)

RL-B-10
ELEV. 4040'
(1231m)

SM
CALICHE
SM
CLAYSTONE
51.6'
(m)

SM
SC
CLAYSTONE
SANDSTONE
CLAYSTONE
SANDSTONE
CLAYSTONE
SANDSTONE
CLAYSTONE
SANDSTONE
CLAYSTONE
SANDSTONE
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SANDSTONE
CLAYSTONE

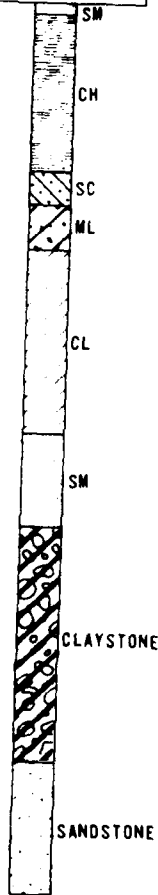
T.D. 302.5'
(92.2m)



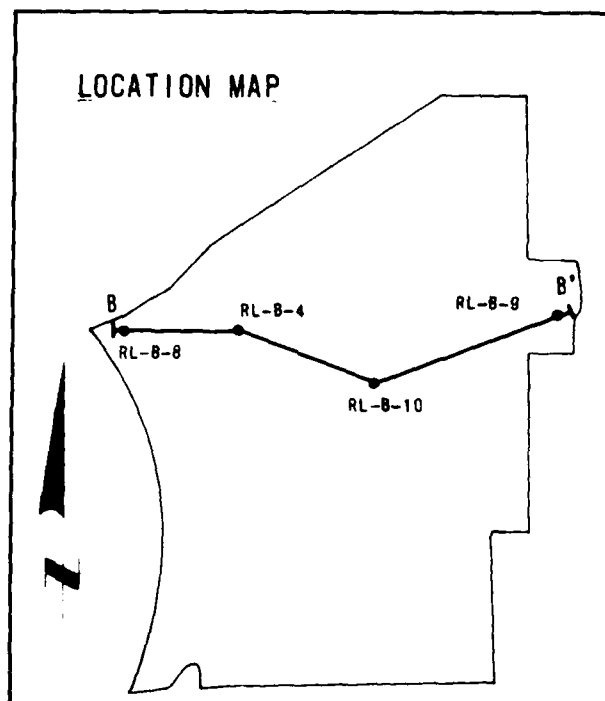
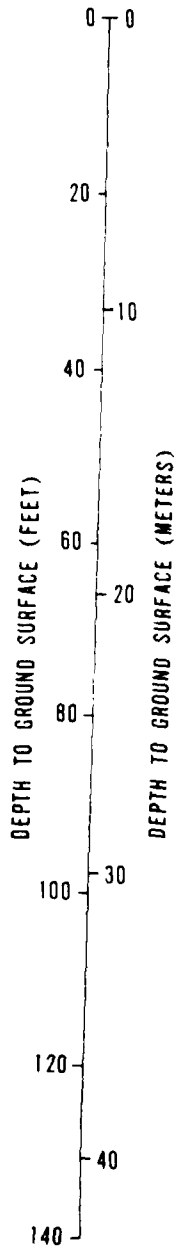
Borings are approximate
based on Unified Soil Classification System

2

RL-B-8
ELEV. 4350' B⁺
(1326m)



T.D. 101.0'
(30.8m)



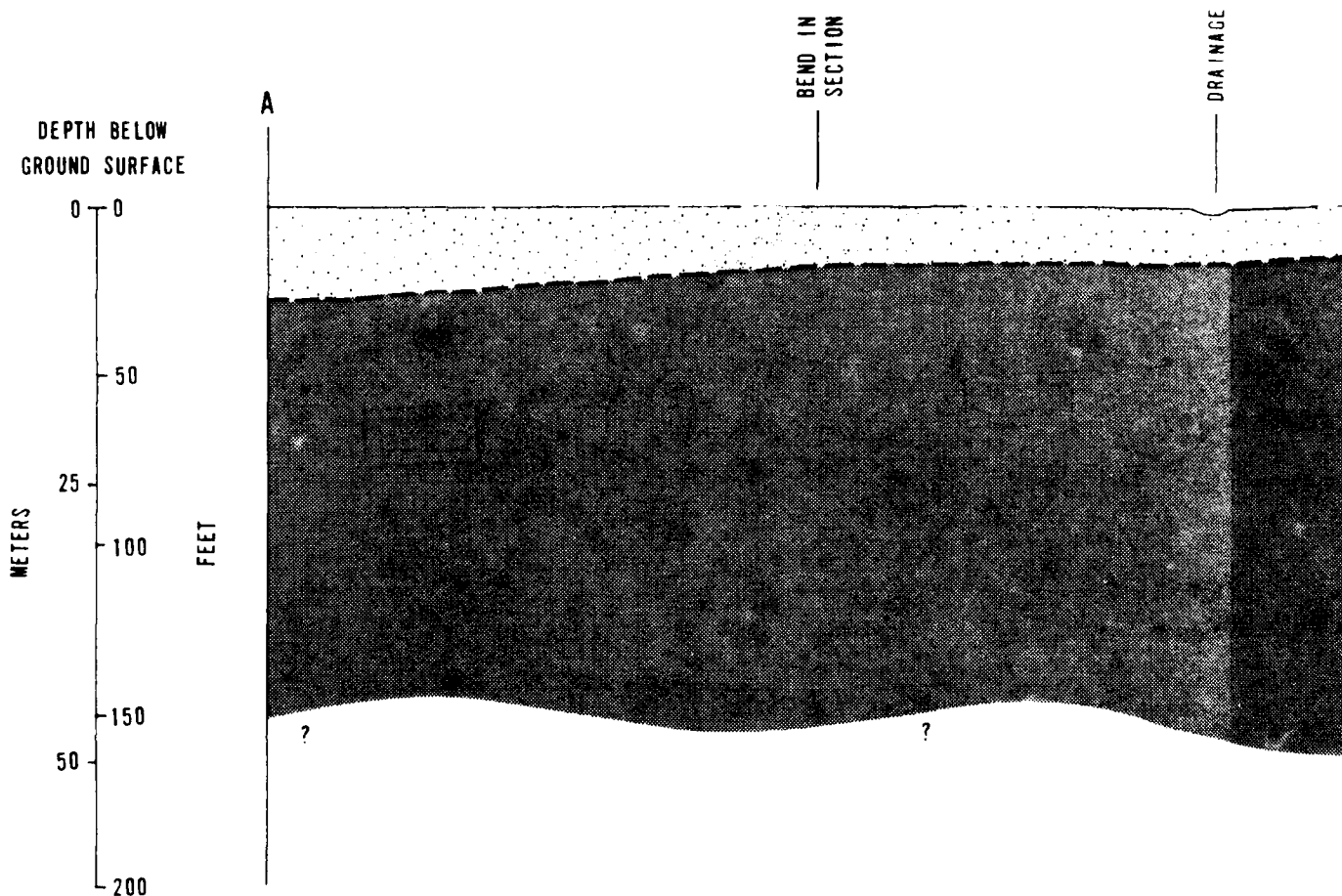
SOIL PROFILE BB'
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SANSO

FIGURE
10

FUGRO NATIONAL, INC.

3



EXPLANATION

NOTES:

1. The cross section is generally representative of subsurface conditions within the band shown on the location map. Due to the limited density of available data and the sparseness of newly acquired data, the subsurface conditions are highly interpretive.

2. For a detailed description of geologic units see Table A-1.



Undifferentiated surficial units

Predominantly eolian (A3) deposits, with terrace (A2) and minor stream channel (A1) and lacustrine and playa (A4) deposits



Ogallala Formation (S5To)

Unconsolidated sand, silt, gravel, cobbles or clay with local caliche caprock



Dockum Group

Sandstone and shale interbedded with gypsum

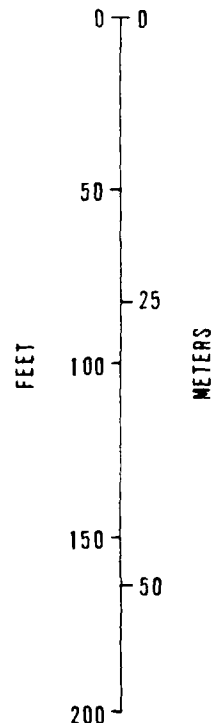
— — —?— Approximate geologic contact, queried where inferred

DRAINAGE

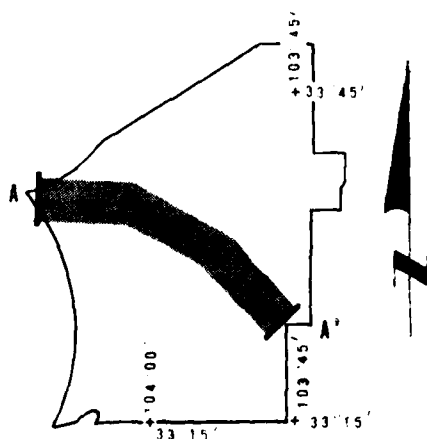
BEND IN
SECTION

A'

DEPTH BELOW
GROUND SURFACE



LOCATION MAP

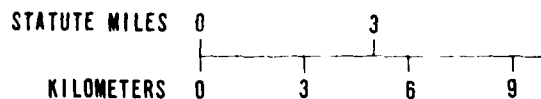


Horizontal Scale: 1" = 3 Miles (4.8km)

Vertical Scale: 1" = 50' (15m)

Vertical Exaggeration: 317X

HORIZONTAL SCALE



GENERALIZED GEOLOGIC CROSS SECTION
ROSWELL SITE, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SANSO

FIGURE

11

FUBRO NATIONAL, INC.

EXPLANATION

SURFICIAL GEOLOGIC UNITS

□ A1, A2, and A3 - stream channel, terrace and eolian deposits

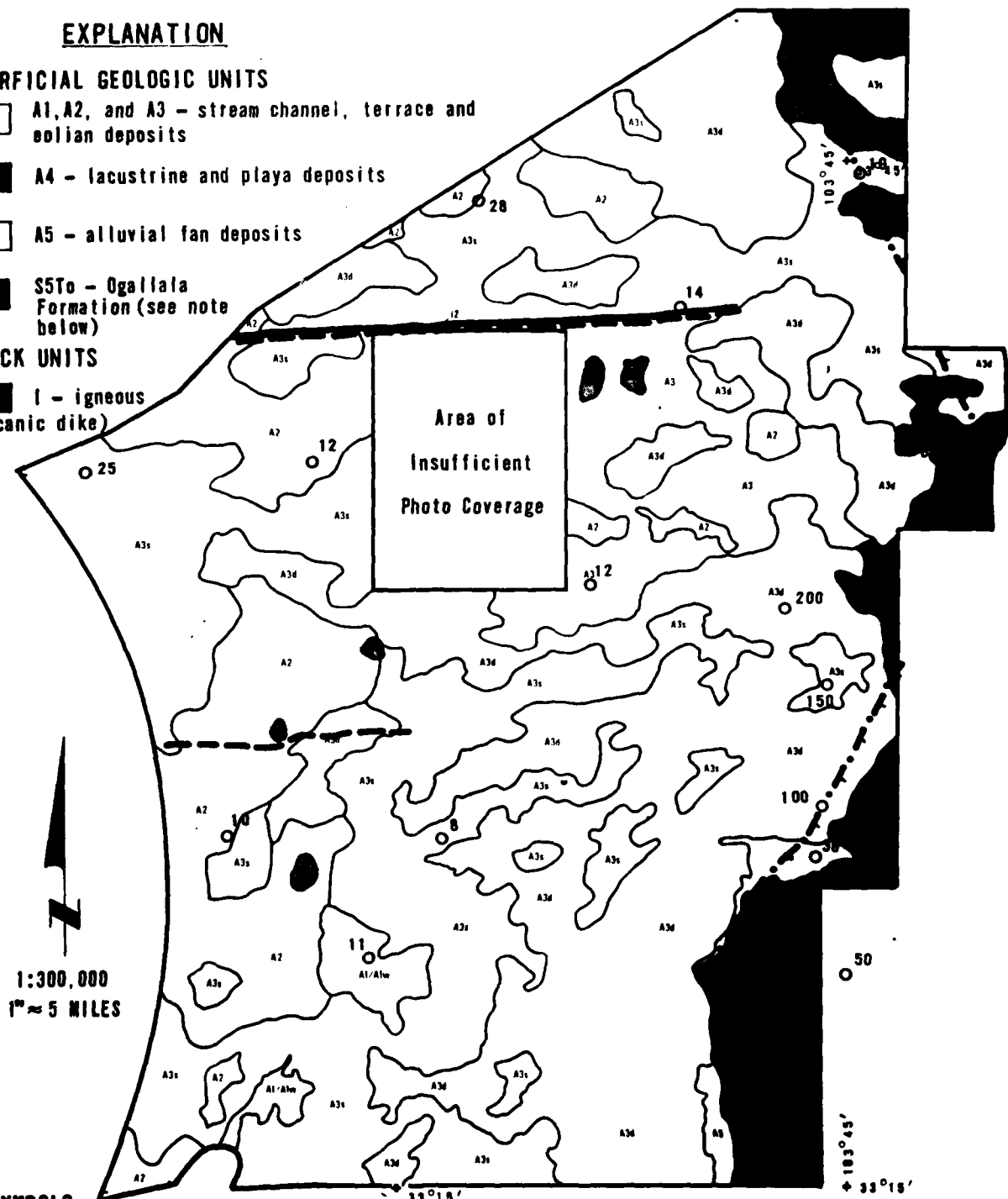
■ A4 - lacustrine and playa deposits

□ A5 - alluvial fan deposits

■ S5To - Ogallala Formation (see note below)

ROCK UNITS

■ I - igneous (Volcanic dike)



SYMBOLS

○¹⁴ Depth to excavatable rock in feet

— Volcanic dikes occurring at or within 150 feet of surface

— Contouring indicates ground water at a depth of approximately 150 feet (hachured side indicates water at approximately 100 feet).

NOTE: For detailed description of geologic units, see Table A-1.

GENERALIZED GEOLOGIC MAP AND
SELECTED SUBSURFACE FEATURES
ROSWELL, NEW MEXICO, SOUTHERN HIGH PLAINS CSP

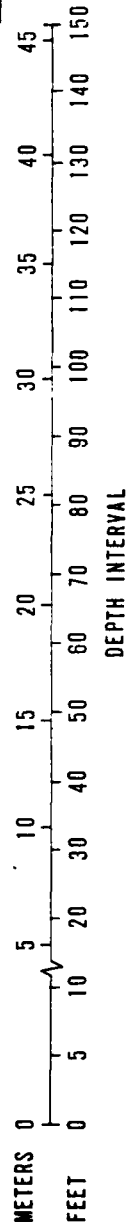
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANSO

FIGURE
12

Following Intermediate Screening, the Ogallala Formation was designated non-rock due to its unconsolidated nature

FUGRO NATIONAL, INC.

SEISMIC LINE NO.	VELOCITY DISTRIBUTION FPS (MPS)		DEEPER REFRACTORS DEPTH VELOCITY	* ROCK EXCLUSION DEPTH TO 7000 FPS (2134 MPS)
RL-S-1	2420 (740)	5270 (1610)	9870 (3010)	-
RL-S-2	2160 (660)	2720 (830)	5010 (1530)	152 (46)
RL-S-3	a	3360 (1020)	10310 (3140)	-
RL-S-4	1795 (550)	3490 (1060)	7530 (2300)	-
RL-S-5	2010 (610)	4580 (1400)	7880 (2400)	-
RL-S-6	6160 (1880)	11455 (3490)	-	-
RL-S-7	1750 (530)	3660 (1120)	7490 (2280)	-
RL-S-8	1070 (330)	2310 (700)	8270 (2520)	-
RL-S-9	1330 (410)	4610 (1410)	8390 (2560)	-
RL-S-10	1290 (390)	2910 (890)	7620 (2320)	-
RL-S-11	2960 (900)	6500 (1980)	104 (32)	-
RL-S-12	1400 (430)	2490 (760)	8370 (2550)	-
RL-S-13	5960 (1820)	6470 (1970)	30 (9)	-
RL-S-14	a 1650 (500)		121 (37)	-



* If no refracting interface or layer with a velocity greater than 7000 fps (rock/rock-like material) was detected, a rock exclusion depth calculation was performed to determine the minimum depth at which rock could occur.

SHALLOW SEISMIC REFRACTION RESULTS ROSWELL, NEW MEXICO SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SANSO

TABLE
12

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ACTIVITY LOCATION*	AVERAGE CONDUCTIVITY (mhos/m)**
R-1	.013
R-2	.025
R-3	.015
R-4	.025
R-5	.098
R-6	.006
R-7	.013
R-8	.053
R-9	.011
R-10	.163
R-11	.028
R-12	.141
R-13	N.D.
R-14	N.D.

*Resistivity was determined using a Schlumberger Array at each location where a seismic refraction survey was conducted.

**Conductivity is the inverse of resistivity. Numbers presented are the average of values determined to a depth of 50 feet, computed as follows:

$$\text{Average Conductivity} = (C_1 t_1 + C_2 t_2 + \dots + C_n t_n) / 50 \text{ feet}$$

Where

Average
Conductivity = mhos/m

C_1 through C_n = Conductivity (mhos/m) of
layers 1 through n

t_1 through t_n = Thickness (feet) of layers
1 through n to 50 feet

CONDUCTIVITY SURVEY RESULTS
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

VI SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE
13

FUGRO NATIONAL, INC.

"Bedrock" velocities (>7000 fps; 2134 mps) were observed at 70 percent of the seismic line locations. The high velocities were caused by either increased cementation, caliche horizons, or the upper part of the Dockum Group or Ogallala formations. Average conductivity values for the upper 50 feet (15 m) of the subsurface ranged from 0.006 to 0.028 mhos/m; and exceed the minimum value of 0.004 mhos/m specified in the Fine Screening Criteria.

3.5 ENGINEERING PROPERTIES

Laboratory tests were performed to determine the engineering properties of the various geologic units. The testing program consisted of classification, consolidation, shear strength, compaction, CBR and chemical tests. The range of engineering and geophysical properties is summarized in Table 14. Sheet and dune sand deposits have been combined into a single category due to their similar characteristics. The terrace deposits consist of sands and silts. Some properties of caliche encountered at the site are not included in Table 14 due to insufficient data. The site soils are generally neither expansive nor collapsible, are moderately compressible, and have moderate shear strengths.

Ranges of gradation of the two dominant geologic units are shown in Figure 13. Table 15 presents the results of chemical tests which indicate the sulfate attack potential of soils on concrete is generally "positive" to "severe".

ENGINEERING AND GEOPHYSICAL PROPERTIES		A3d + A3s
UNIFIED SOIL CLASSIFICATION SYMBOL(S)		SC, SM, CL, ML
GENERAL PROPERTIES		
DRY DENSITY	pcf(kg m ³)	93-126 (1490-2018)
MOISTURE CONTENT	(%)	3-20
DEGREE OF SATURATION	(%)	15-95
SPECIFIC GRAVITY		2.64±
DEGREE OF CEMENTATION		None to strong
COMPRESSIONAL WAVE VELOCITIES	fps(mps)	1330-4610 (405-1405)
ELECTRICAL CONDUCTIVITY	(mhos m)	0.011±
GRAIN SIZE DISTRIBUTION (%)		
BOULDERS	>12 inches (30cm)	0
COBBLES	3 to 12 inches (8 to 30cm)	0-3
GRAVEL		0-20
SAND		0-81
SILT AND CLAY		9-88
PLASTICITY DATA		
LIQUID LIMIT		22-33
PLASTICITY INDEX		NP-14
COMPRESSIBILITY DATA		
COMPRESSION AT 4 ksf (192 kN/m ²)	(%)	2.4±
SWELL OR COLLAPSE UPON SATURATION	(%)	0.1±
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION	ksf(kN m ²)	12.2-24.4 (584-1168)
CD TRIAXIAL COMPRESSION		C=0-2 (96) θ =27-35
DIRECT SHEAR	ksf(kN m ²)	1.1-7.2 (53-345)
COMPACTION AND CBR DATA		
MAXIMUM DRY DENSITY	pcf(kg m ³)	122-128 (1954-2053)
OPTIMUM MOISTURE CONTENT	(%)	10-12
CBR AT 90% RELATIVE COMPACTION		6-41

*NP=Not Plastic

**DNA=Data Not Available

GEOLOGIC UNITS

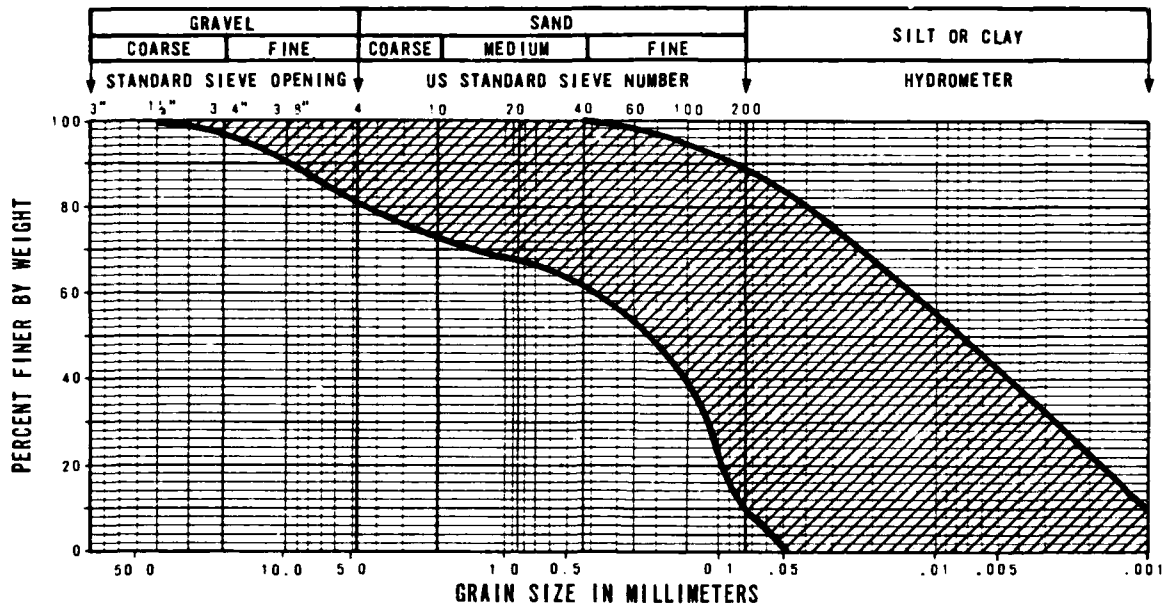
	A2
	SM, SC, CL, GC, GM, GP
	90-140 (1442-2243)
	2-25
	18-100
	2.62-2.72
	None to strong
	1750-3655 ± (533-1114)
	0.0053 ±
	0-5
	0-10
	0-69
	0-82
	18-96
	24-40
	NP ²⁴
	1.5-1.7
	0.1-0.2
	1.8-5.4 (86-259)
	C = 0-4 (192) B = 27-39
	3.2-5.7 (153-273)
	DNA ^{**}
	DNA
	DNA

RANGE OF ENGINEERING AND
GEOPHYSICAL PROPERTIES
ROSWELL, NEW MEXICO, SOUTHERN HIGH PLAINS CSP

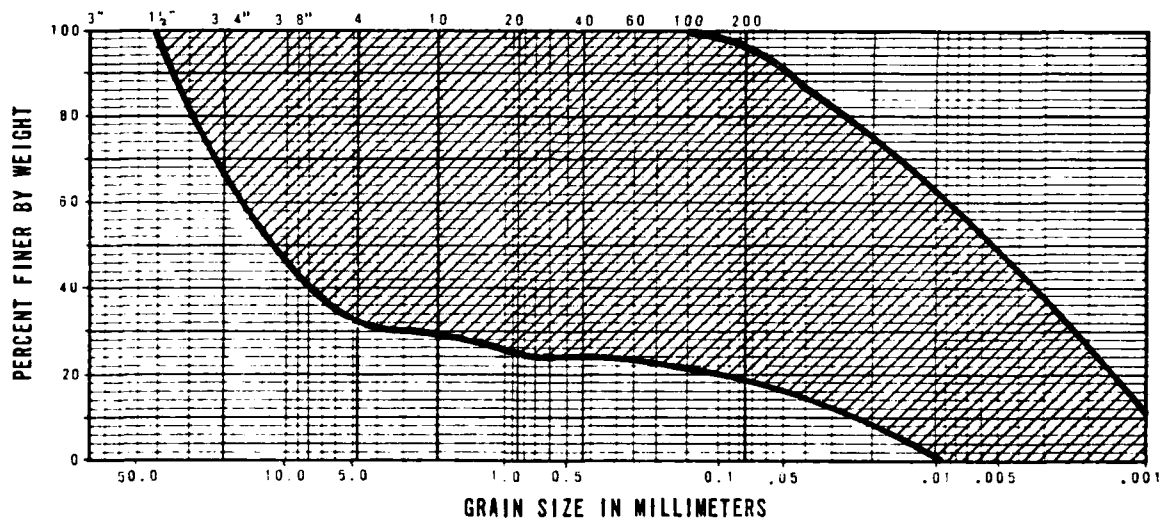
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSQ

TABLE
14

FUGRO NATIONAL, INC.



A3d and A3s



A2

RANGE OF GRADATION OF GEOLOGIC UNITS
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
13

FUGRO NATIONAL, INC.

[illegible]

*Weakly to moderately cemented claystone

SUMMARY OF CHEMICAL TEST RESULTS
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

**TABLE
15**

FUGRO NATIONAL, INC.

Representative logs of three borings and three trenches from the site are contained in Appendix C. Results of the shear strength and CBR tests performed on samples from the site and a summary of all the laboratory tests performed on soil samples obtained from boring RL-B-10 are also included in Appendix C.

4.0 DISCUSSION

Analysis of data collected and analyzed for the Muleshoe and Roswell sites indicate many similarities and some dissimilarities in the general geologic conditions of the two sites. The apparent similarities are:

- o Eolian sheet and dune sand deposits are the predominant surficial geologic units.
- o A significant portion (15 to 20 percent) of each site is underlain by resistant layers of well-cemented caliche.
- o Surface slopes are generally less than three percent, except in areas of dunes where slopes may reach 30 percent.
- o Surface drainage consists of ephemeral streams that are generally wide and irregularly spaced many miles apart.
- o The engineering characteristics of the geologic units at the two sites are similar, however, there are differences between the aerial extent of these units at each site.

Some dissimilar features are:

- o The presence of terrace deposits in the Roswell site that form a thin veneer five to ten feet (1.5 to 3 m) thick over Triassic rocks of the Dockum Group.
- o The Muleshoe site is underlain entirely by the Ogallala Formation. Well indurated caliche caprock is locally present in the upper ten feet (3 m) of this formation. The Roswell site is underlain primarily by Dockum Group, consisting of sandstone and shale with interbedded gypsum.

- o Depth to water is less than 150 feet (46 m) over approximately 90 percent of the Muleshoe site. In the Roswell site, less than five percent of the area is expected to contain shallow water.

Based on regional geologic information, geotechnical conditions at the Muleshoe and Roswell sites are representative of approximately 75 percent of the Southern High Plains CSP. For areas beyond these specific sites some variability in conditions does exist. For example, the area north of the Muleshoe site has a thicker and finer grained eolian mantle. West of the Roswell site and west of the Pecos River, the primary surficial unit is terrace deposits which range in thickness from zero to 300 feet (91 m). The suitable area not characterized by the Muleshoe and Roswell sites is located in the southernmost portion of the CSP and lies within the Basin and Range physiographic province. It is generally characterized by broad alluvial plains with local hills and mesas underlain by Cretaceous and Tertiary bedrock.

5.0 CONSTRUCTION CONSIDERATIONS

In this section, geotechnical factors and conditions applicable to construction of the MX system are discussed. The three basing mode concepts considered are vertical shelter, in-line hybrid trench, and horizontal shelter.

The important geotechnical factors for a vertical shelter are roads (primary, secondary, and interconnecting), drainage crossings, and excavation of shelters. For the in-line hybrid trench, important geotechnical factors are excavation and backfill, roads (primary, secondary, and temporary), drainage crossings, and aggregates for roads and concrete. For the horizontal shelter, roads and drainage crossings are the important geotechnical factors. A brief summary of the applicable geotechnical factors is presented in the following paragraphs.

- o Terrain - Surficial slopes are typically less than three percent, except in dune areas, requiring little preconstruction grading for roads and trenches. Maximum depths of drainage incision are generally less than ten feet (3 m) for the Roswell site and 30 feet (9 m) for the Muleshoe site. Due to the wide spacing of these drainages, relatively few major drainage structures will be needed.
- o Roads - An extensive network of paved and unpaved federal, state and county roads traverse the Muleshoe site, reducing the need for new roads. The surficial soils at Muleshoe have good subgrade characteristics. Fewer roads exist at the Roswell site and, therefore, a network of new roads

will be required. In approximately 40 percent of the Roswell site, surficial soils have poor road subgrade characteristics.

- o Excavation - Except for the caliche, subsurface soils are generally suited for excavation by an MX trencher and conventional excavations required for the horizontal shelter. In areas of caliche either conventional excavation equipment or blasting may be required.

In Muleshoe site, well indurated caliche is present and therefore additional expense will be required for excavation of vertical shelters. In addition, depth to ground water over most of the site is less than 150 feet (46 m) resulting in additional excavation costs for vertical shelters.

In Roswell site, excavatable rock (Dockum group) exists within the construction zone (150 ft; 46 m) requiring additional expense. In some localized areas blasting may be necessary. Depth to ground water is greater than 150 feet (46 m), thus, ground water problems during excavation are expected to be minimal.

- o Backfill - Subsurface soils are generally suitable for backfill and compaction in trench excavations and minimum compactive effort will be required. Backfill will have to be imported from within the sites in areas of extensive caliche.
- o Aggregates and Water - For both sites, sufficient quantities of fine aggregate for concrete and road construction are available in the site vicinity.

Sufficient quantities of coarse aggregate for concrete and road construction are not available in the vicinity of Muleshoe site and will have to be hauled from distances greater than 50 miles (80 km). However, sufficient quantities of coarse aggregate are available in the vicinity of Roswell site.

Adequate quantities of water are available from existing wells at the Muleshoe site, but additional wells will be needed at the Roswell site.

6.0 CONCLUSIONS

In summary, the Muleshoe and Roswell sites present favorable geotechnical conditions for deployment of in-line hybrid trench and horizontal shelter MX basing modes. They are also suitable for vertical shelter basing mode, but excavation costs will be high due to the presence of rock and ground water within the construction zone. Geotechnical conditions from these two sites can be extrapolated to approximately 75 percent of the Southern High Plains CSP.

APPENDIX A
GENERAL GEOTECHNICAL INFORMATION

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APPENDIX A

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GLOSSARY OF TERMS

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number; may also be used to designate a particular location in a valley.

AEROMAGNETIC DATA - Magnetometer observations made from an airplane.

ALLUVIAL BASIN - A lowland area, generally between uplifted mountain blocks, filled with alluvial deposits.

ALLUVIAL FAN - A low, outspread, relatively flat to gently sloping mass of alluvium, shaped like an open fan or a segment of a cone, deposited by a stream (especially in a semiarid region) at the place where it issues from a narrow mountain valley upon a plain or broad valley. It is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with gradually decreasing gradient.

ALLUVIAL FAN DEPOSITS - Alluvium deposited by a stream or other body of running water as a sorted or semisorted sediment in the form of a cone or fan at the base of a mountain slope.

ALLUVIAL PLAIN - A level or gently sloping tract or a slightly undulating land surface produced by extensive deposition of alluvium, usually adjacent to a river that periodically overflows its banks; it may be situated on a flood plain, a delta, or an alluvial fan.

ALLUVIUM - A general term for unconsolidated clay, silt, sand, gravel, and boulders deposited during relatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

ANOMALY - 1) A deviation from uniformity in physical properties; especially a deviation from uniformity in physical properties of exploration interest. 2) A portion of a geophysical survey which is different in appearance from the survey in general.

AQUIFER - A permeable saturated zone below the earth's surface capable of conducting and yielding water as to a well.

GLOSSARY OF TERMS (Cont.)

ARKOSIC SANDSTONE - A sandstone with considerable feldspar, such as one containing minerals from coarse-grained quartzo-feldspathic rocks (granites, granodiorites, medium or high-grade schists) or from older, highly feldspathic sedimentary rocks; specifically a sandstone containing more than 25% feldspar and less than 20% matrix material of clay, sericite, and chlorite.

ARRIVAL - An event; the appearance of seismic energy on a seismic record; a line-up of coherent energy signifying the arrival of a new wave train.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid limit (LL) - The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D423-66).

Plastic limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D424-59).

Plasticity index (PI) - Numerical difference between the liquid limit and the plastic limit.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogenous detrital material deposited in a sedimentary basin.

BEDROCK - Rock with a seismic p-wave velocity of 7000 ft (2333 m) per second or more.

BOUGUER ANOMALY - The residual value obtained after latitude, elevation and terrain corrections have been applied to gravity data.

BOULDER FIELD - Five or more rocks, each with diameters of 6 ft or more occurring within an acre.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench excavation.

c - Cohesion (Shear strength of a soil not related to inter-particle friction).

CALICHE - Gravel, sand or other material cemented principally by calcium carbonate.

GLOSSARY OF TERMS (Cont.)

- CALIFORNIA BEARING RATIO (CBR) - A test performed on a specifically prepared soil sample which is useful in the design of road pavement to be supported by the soil tested (ASTM D1833-73). The load is applied on the penetration piston which is penetrated into the soil sample at a constant penetration rate. The bearing ratio reported for the soil is normally the one at 0.1 inches (2.5 mm) penetration.
- CANDIDATE - One of some group of regions, areas or sites being considered for MX deployment. Removal of candidate from a specifically named region, area or site term indicates selection by SAMSO/MNND.
- CANDIDATE DEPLOYMENT AREA (CDA) - An area encompassing between 500 and 1000 square nautical miles of potentially suitable land with either naturally or artificially defined boundaries designated for convenience of study, discussion and data depiction. The candidate deployment area could be composed of two to four parcels and should have a specific place name description.
- CANDIDATE DEPLOYMENT PARCEL (CDP) - An area of 150 to 500 square nautical miles potentially suitable for MX siting which, when aggregated with others, forms a Candidate Deployment Area. Each parcel should have a specific geographic description. (In the Basin and Range Physiographic province a parcel may correspond to a geographic valley and in Texas to some agri-economic unit.)
- CANDIDATE DEPLOYMENT SITE (CDS) - A non-specific (i.e. not finally approved) site proposed for some element of the MX system within a chosen deployment area (i.e. trench or shelter site).
- CANDIDATE SITING PROVINCE (CSP) - An area potentially suitable for deployment of the MX system generally encompassing more than 6000 square nautical miles which, in a broad sense, is homogeneous with respect to most of the important characteristics governing siting of a total MX system.
- CANDIDATE SITING REGION (CSR) - Potentially suitable area between 4000 and 6000 square nautical miles within one, or encompassing portions of more than one, candidate siting province which allows for full MX deployment.

GLOSSARY OF TERMS (Cont.)

- CAPABLE (fault) - Movement at or near the surface at least once in the past 35,000 years, and/or more than once in the past 500,000 years, (Nuclear Regulatory Commission).
- CAPROCK - A resistant, moderately to strongly cemented caliche layer forming a "cap" over less resistant layers.
- CD TRIAXIAL SHEAR-A type of test to measure the shear strength of an undisturbed soil sample
- CLOSED BASIN - A catchment area draining to some depression or lake within its area, from which water escapes only by evaporation.
- COARSE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.075 mm in diameter (passing the No. 200 U.S. size).
- COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material larger than 3 inches (76 mm) in diameter.
- COLLUVIAL DEPOSITS - A general term applied to any loose, heterogenous, and incoherent mass of soil material or rock fragments deposited chiefly by dislodgement and downslope transport of the material under the direct application of gravitational body stresses. Material is usually found at the base of a steep slope or cliff.
- COMPACTION TEST - A type of test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D1557-70).
- COMPRESSIBILITY-Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.
- COMPRESSIONAL WAVE -An elastic body wave in which particle motion is in the direction of propagation; the type of seismic wave assumed in conventional seismic exploration. Also called P-wave, dilatational wave, and longitudinal wave.
- CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

GLOSSARY OF TERMS (Cont.)

- CONTERMINOUS UNITED STATES - The contiguous 48 states.
- CORE SAMPLE - A cylindrical sample obtained with a rotating core barrel with a cutting bit at its lower end. Core samples are obtained from indurated deposits and in rock.
- DEBRIS FLOW - A high-density flow of mud containing abundant coarse-grained materials (boulders, cobbles, gravel, sand) that frequently result from an unusually heavy rain.
- DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.
- DETECTOR - See GEOPHONE.
- DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.
- DISSECTION/DISSECTED (alluvial fans) - The cutting of stream channels into the surface of an alluvial fan by the movement (or flow) of water.
- DISTAL - That portion of an alluvial deposit farthest from its point of origin.
- DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.
- ELECTRICAL CONDUCTIVITY - Ability of a material to conduct electrical current
- ELECTRICAL RESISTIVITY - Property of a material which resists flow of electrical current
- ENTRENCH - The process whereby a stream erodes downward to form a trench.
- EOLIAN - A term applied to materials which are deposited by wind.
- EPHEMERAL(stream) - A stream in which water flow is discontinuous and of short duration.
- EXTERNAL DRAINAGE - Stream drainage system whose downgradient flow is unrestricted by any topographic impediments.
- EXTRUSIVE (rock) - Igneous rock that has been ejected onto the earth's surface (e.g., lava, basalt, rhyolite, andesite; detrital material, volcanic tuff, pumice).

GLOSSARY OF TERMS (Cont.)

- FAULT** - A plane or zone of rock fracture along which there has been displacement.
- FAULT BLOCK MOUNTAINS** - Mountains that are formed by normal faulting in which the surface crust is divided into structural, partially to entirely fault-bounded blocks of different elevations.
- FINE-GRAINED** - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.075 mm in diameter (passing the No. 200 U.S. size sieve).
- FINER-GRAINED** - A term applied to alluvial fan deposits, which are composed predominantly of material less than 3 inches (76 mm).
- FLOODING/LOW ENERGY FLOW** - Flood waters flowing on a slope of low gradient.
- FLUVIAL DEPOSITS** - Material produced by river action; generally loose, moderately well-graded sands and gravel.
- FORMATION** - A mappable assemblage of rocks characterized by some degree of homogeneity or distinctiveness.
- FREE AIR ANOMALY** - Gravity data which have been corrected for latitude and elevation (free air correction) but not for the density of rock between the datum and the plane of measurement (Bouguer correction).
- FUGRO DRIVE SAMPLE** - A 2.50 inch (6.4 cm) diameter soil sample obtained from a drill hole with a Fugro Drive Sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 one-inch (2.54 cm) long brass sample rings. The sampler is advanced into the soil using a drop-hammer.
- GAMMA** - A unit of magnetic-field intensity. A gamma is 10^{-5} oersteds; sometimes expressed (incorrectly) as 10^{-5} gauss with which it is numerically equal.
- GEOMORPHOLOGY** - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features.
- GEOPHONE** - The instrument used to transform seismic energy into electrical voltage; a seismometer, jug, or pick-up.

GLOSSARY OF TERMS (Cont.)

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.075mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of the particle sizes smaller than 0.075 mm is determined by a sedimentation process, using a hydrometer.

GRAVEL - Particles of rock that pass a 3-in. (76.2 mm) sieve and retained on a No. 4 (4.75 mm) sieve

GRAVITY - The force of attraction between bodies because of their mass. Usually measured as the acceleration of gravity.

GRAVITY GRADIENT - The partial derivative of the acceleration of gravity with respect to distance in a particular direction, for which purpose the acceleration of gravity is considered as a scalar.

INTERIOR DRAINAGE - Stream drainage system that flows into a closed topographic low (basin).

INTRUSIVE (rock) - A rock formed by the process of emplacement of magma (liquid rock) in pre-existing rock. (e.g. granite, granodiorite, quartz monzonite).

LACUSTRINE DEPOSITS - Materials deposited in lake environment.

LINE - A linear array of observation points, such as a seismic line.

LIQUID LIMIT - See ATTERBERG LIMITS.

LOESS - A wind blown deposit predominantly silt or silty clay or clayey silt.

LOW ENERGY FLOW - See FLOODING.

MAGNETIC INTENSITY - A vector quantity measuring magnetic field strength. The unit of magnetic intensity commonly used in geophysical exploration is the gamma (see GAMMA).

MANTLED PLAYA - A playa surface or a portion of the surface that is covered with younger geologic material such as windblown sand, or alluvium.

MILLIGAL - A unit of acceleration used with gravity measurements; 1 milligal = 10^{-5} m/sec.². Abbreviated mgal.

GLOSSARY OF TERMS (Cont.)

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the oven-dry weight of the sample.

N VALUE - Penetration resistance, number of blows required to drive the standard split spoon sampler for the second and third six inches (0.15 m) with a 140 pound (63.5 kg) hammer falling 30 inches (0.76 m) (ASTM D1586-67).

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort

OVERBANK FLOODING - A large flow of water that overflows the sides of a stream channel.

O - Angle of internal friction

PATINA - A dark coating or thin outer layer produced on the surface of a rock or other material by weathering after long exposure (e.g., desert varnish).

PAVEMENT/DESERT PAVEMENT - When loose material containing pebble-sized or larger rocks is exposed to rainfall and wind action the finer dust and sand are blown or washed away and the pebbles gradually accumulate on the surface, forming a mosaic which protects the underlying finer material from wind attack. Pavement can also develop in finer-grained materials. In this case the armored surface is formed by dissolution and cementation of the grains involved.

PEGMATITE DIKE - A coarse grained igneous rock of granitic composition that forms as a tabular intrusion that cuts across the planar structures of the surrounding rock.

P-WAVE - See COMPRESSIONAL WAVE.

PERIMETER SEISMIC REFRACTION SURVEY - Shallow seismic refraction measurements made around the perimeter of a valley.

PERMEABLE - The ability of liquid to pass through soil and/or rock material.

PICK-UP - See GEOPHONE.

GLOSSARY OF TERMS (Cont.)

- PITCHER TUBE SAMPLE - An undisturbed, 2.87 inch (73 mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending upon the hardness of the material being penetrated.
- PLASTIC LIMIT - See ATTERBERG LIMITS.
- PLASTICITY INDEX - See ATTERBERG LIMITS.
- PLAYA/PLAYA DEPOSITS - A term used in the southwest U.S. for a dried-up, flat-floored area composed of thin, evenly stratified sheets of fine clay, silt, or sand, and representing the lowest part of a shallow, completely closed or undrained, desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.
- PONDING (of water) - The accumulating of water in a topographic depression.
- PRIME - Modifier used to indicate the highest ranking province, region, area, or site. If not an interdisciplinary ranking, then a qualifier should be used such as "prime" geotechnical candidate siting area".
- PROXIMAL - That portion of an alluvial deposit nearest to its point of origin.
- REGIONAL - The general attitude or configuration disregarding features smaller than a given size. The regional gravity is the gravity field produced by large-scale variations ignoring anomalies of smaller size. See residualize.
- RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.
- RESIDUAL - What is left after a regional field has been removed, as in gravity or magnetic analysis. See RESIDUALIZE.

GLOSSARY OF TERMS (Cont.)

RESIDUALIZE - The process of separating a graphically depicted curve or a surface into its low-frequency parts (called the regional) and its high-frequency parts (called the residual). Residualizing is an attempt to sort out of the total field those anomalies which result from local structure; that is, to fine local anomalies by subtracting gross (regional) effects.

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

S-WAVE - See SHEAR WAVE.

SAND - Soil passing through No. 4(4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves (shear waves).

SEISMIC REFRACTION DATA: deep/shallow - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and of distance from the shot, by determining the arrival times of seismic waves which have travelled nearly parallel to the bedding in high-velocity layers, in order to map the depth to such layers.

SEISMOGRAM - A seismic record.

SEISMOMETER - See GEOPHONE.

SHEAR WAVE - A body wave in which the particle motion is perpendicular to the direction of propagation. Also called S-Wave or transverse wave.

SHEET FLOW - A process in which storm-borne water spreads as a thin, continuous veneer (sheet) over a large area.

SHEET SAND - A blanket deposit of sand which accumulates in shallow depressions or against rock outcrops, but does not have characteristic dune form.

SHOT - Any source of seismic energy; e.g., the detonation of an explosive.

GLOSSARY OF TERMS (Cont.)

- SHOT POINT** - The location of any source of seismic energy; e.g., the location where an explosive charge is detonated in one hole or in a pattern of holes to generate seismic energy. Abbreviated SP.
- SILT AND CLAY** - Fine-grained soil passing through No. 200 (0.075 mm) sieve.
- SITE** - Location of some specific activity or reference point. The term should always be modified to a precise meaning or be clearly understood from the context of the discussion.
- SPECIFIC GRAVITY** - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.
- SPLIT SPOON SAMPLE** - A disturbed sample obtained with a split spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop-hammer.
- SPREAD** - The layout of geophone groups from which data from a single shot are recorded simultaneously. Spreads containing twenty-four geophones have been used in Fugro's seismic refraction surveys.
- STREAM CHANNEL DEPOSITS** - Materials (clay, silt, sand, gravel, cobbles, boulders) which have been deposited in a stream channel.
- STREAM TERRACE DEPOSITS** - Stream channel deposits no longer part of an active stream system, generally loose, moderately well graded sand and gravel.
- SURFICIAL DEPOSIT** - Unconsolidated residual and alluvial deposits occurring on or near the earth's surface.
- TRANSITORY** - A poorly defined, shallow ephemeral stream across an alluvial fan surface, the position of which is temporary and tends to shift frequently.
- UNCONFINED COMPRESSION** - A type of test to measure the compressive strength of an undisturbed soil sample.
- UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)** - A system which determines soil classification on the basis of grain-size distribution and Atterberg Limits. (See page A-17).

GLOSSARY OF TERMS (Cont.)

VALLEY SEISMIC REFRACTION SURVEY - Deep seismic refraction measurements made near the middle of a valley to determine seismic wave propagation velocities and thickness of basin fill.

VELOCITY - Refers to the propagation rate of a seismic wave without implying any direction. Velocity is a property of the medium and not a vector quantity when used in this sense.

VELOCITY LAYER - A layer of rock or soil with a homogenous seismic velocity.

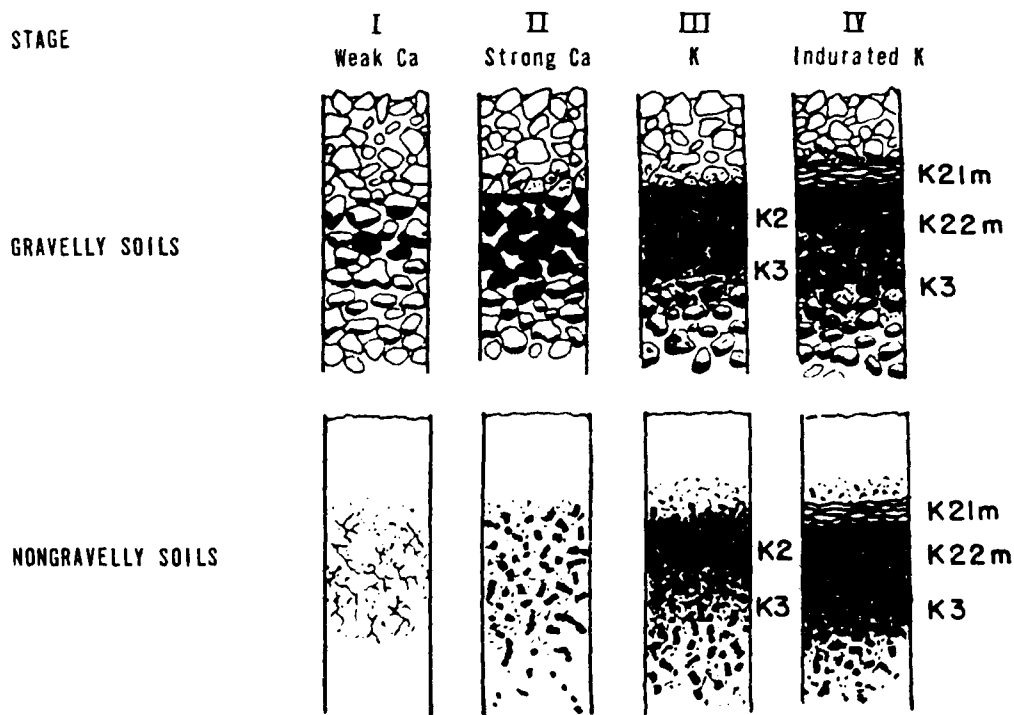
VELOCITY PROFILE - A cross-section showing the distribution of material seismic velocities as a function of depth and its configuration.

WASH SAMPLE - A sample obtained by screening the returned drilling fluid during rotary wash drilling to obtain lithologic information between samples.

Definitions were derived in part from Webster's New Collegiate Dictionary (1972 edition), Glossary of Geology (American Geological Institute, 1972), Encyclopedic Dictionary of Exploration Geophysics (Sheriff, 1973), and 1976 Annual Book of ASTM Standards.

DIAGNOSTIC CARBONATE MORPHOLOGY

STAGE	GRAVELLY SOILS	NONGRAVELLY SOILS
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Laminar horizon overlying plugged horizon



Stages of development of a caliche profile with time. Stage I represents incipient carbonate accumulation, followed by continuous build-up of carbonate until, in Stage IV, the soil is completely plugged.

SUMMARY OF CALICHE DEVELOPMENT

Reference: Gile, L. H., Peterson, F. F., and Grossman, R. B., 1965. The K horizon: A master horizon of carbonate accumulation. Soil Science, v. 99, p. 14-22.

WE SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE JAMSO

FIGURE
A-1

FUGRO NATIONAL

(1) AREI
SYMBOLS

MX (2)
GEOLOGIC
UNITS

NON-ROCK UNITS

(1) AREI
SYMBOLS

MX
GEOLOGIC
UNITS

Au, Ast	Au	Non-rock Deposits (undifferentiated); fine- to coarse-grained materials deposited by alluvial, fluvial, eolian, lacustrine, gravity or glacial processes.		
Aal	A1	Fluvial Deposits; predominantly composed of poorly- to well-graded sand and gravel with lesser amounts of silt- and boulder-sized material. The unit predominantly consists of recent water-laid deposits occupying present drainages and flood plains. - Older Fluvial Deposits (A1o) are generally thicker, more extensive units deposited in ancestral fluvial systems. - Alluvial Outwash Deposits (A1w) consist of mixed, geomorphically nondescript alluvial and fluvial deposits covering large, relatively flat, river and playa basins.	gr Vu Vb	I
At	A2	Terrace Deposits; predominantly composed of moderately to well graded, clay- to gravel-sized material. Principally elevated terraces bordering modern streams (A2s) and lakes playas (A2l).	Su	S
	A3	Eolian Deposits; predominantly composed of poorly graded sand-sized material deposited by wind action. Deposits may consist of mixed sand, silt, and clay (A3u), or be differentiated on the basis of predominant grain size and landform. A3s d - Predominantly fine sand-sized material deposited in sheets (A3s) or dunes (A3d). A3l - Loess composed predominantly of silt-sized material with lesser amounts of clay and fine sand. A3f - Predominantly clay-sized material with lesser amounts of silt and fine sand.	Qtz Psa, Pm, Ph, Cau, Ls, Py, Par	
	A4	Lacustrine, Estuarine, and Playa Deposits; predominantly composed of poorly graded clay, silt, and fine sand deposited in bodies of standing water. Older lacustrine, estuarine, and playa deposits (A4o) are thicker, more extensive units occupying ancestral lake basins.	Qtz, gn	M
Aaf	A5	Alluvial Fan Deposits; predominantly composed of well graded sand and gravel with varying amounts of silt-, cobble-, and boulder-sized material. Deposited principally by distributary channels adjacent to mountain fronts. Relative ages are indicated by o - older, i - intermediate, or y - younger.		C
	A6	Pediment, Pediment Deposits, and Areas of Shallow Rock; planated bedrock shelf or near surface rock generally overlain by a thin mantle of sand- to boulder-sized residual or alluvial material.		
	A7	Colluvial Deposits; predominantly composed of moderately- to well-graded sand and gravel with varying amounts of silt-, cobble-, and boulder-sized material. Deposited locally by gravity and water adjacent to steep gradients.		

NOTES (1) AREI symbols were developed for use in the Aggregate Resources Evaluation Investigation (See Section 5.1 and Drawings 5.1A through 5.1C)

(2) MX Geologic units were used for Methodology, Screening, and Characterization studies.

(1) AREI SYMBOLS
 (2) MX GEOLOGIC UNITS

ROCK UNITS

Shown in regions where rock is exposed; the areally predominant (greater than 70 percent) rock type is indicated. In those areas where two rock types occur the predominant rock type is shown followed by the subordinate rock type (e.g. S2MP I4T).

I IGNEOUS (UNDIFFERENTIATED). Rocks formed by solidification of a molten or partially molten mass.

- gr I1 Intrusive - Typically crystalline, formed by the solidification of molten material below the surface (e.g., granite, syenite, diorite).
- Vu I2 Extrusive (undifferentiated). Formed by solidification of molten material at or near the surface.
- Vb I3 Extrusive (flows). Extrusive rocks formed by solidification of lava (e.g. basalt, dacite). I3 denotes young basaltic flows which may be interbedded with basaltic materials.
- I4 Extrusive (volcaniclastics). Formed by accumulation, welding and or cementation of deposits of volcanic ejecta (e.g. tuff, agglomerate, lapilli).

Sb S SEDIMENTARY (UNDIFFERENTIATED). Coarse- to fine-grained materials that exhibit some degree of cementation and were deposited by water, wind, gravity, or evaporation.

- Qtz S1 Sandstone. Composed predominantly of sand-sized particles.
- Psa, Pm, S2 Limestone and Dolomite. Composed predominantly of carbonate material.
- Ph, Cau, S3 Shale. Composed predominantly of clay- and silt-sized particles (e.g. shale, siltstone, mudstone).
- Ls, Py, S4 Evaporites. Sediments deposited from solution as a result of evaporation (e.g. gypsum, anhydrite, halite).
- Par S5 Clastics. Undifferentiated deposits composed of silt- to boulder-sized material. May be angular to rounded.

Qtz, gn M METAMORPHIC (UNDIFFERENTIATED). Rocks formed through alteration of igneous or sedimentary rock material by pressure, heat, or chemical changes below the weathered zone (e.g. gneiss, schist, slate, marble, quartzite).

C ROCK COMPLEXES. Indicated where no areally predominant (greater than 70 percent) rock type is present.

USAGE

Modifying letter (r) indicates concentrations of resistant secondary carbonate (caliche), silicious, ferruginous and or gypsiferous material, e.g. A5ir.

A3s A5y - Mixed non-rock units; most areally extensive unit is listed first.

A5y(A5i) - Parenthetic unit underlies thin veneer of overlying mapped unit.

S5to - Established formations may have a supplementary letter added to distinguish formal designation (e.g. Tertiary Ogallala Fm.).

EXPLANATION OF GEOLOGIC UNITS

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMSU

TABLE
 A-1

FUGRO NATIONAL INC.

Major Divisions		Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 inches and having fractions on estimated weights)	Information Required for Describing Soils						
1	2	3	4	5	6						
Highly Organic Soils	More than half of material is <u>smaller</u> than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.	Five grained soils Liquid limit greater than 50	Silt and Clays	For undisturbed soils and information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. Give typical name; indicate approximate percentages of sand and gravel, max. size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses. Example: Silty sand; gravelly; about 20% hard; angular gravel particles 1/4-in. maximum size; rounded and sub-angular sand grains coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand. (SM).						
						ML	Inorganic silts and very fine sands, rock flour, silty or clayey silts, or clayey silts with slight plasticity.	None to slight	Quick to slow	None	
						CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium	
						OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Slow	Slight	
						MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Slight to medium	Slow to none	Slight to medium	
						CH	Inorganic clays of high plasticity, f. clays.	High to very high	None	High	
						OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium	
						Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.			
						Non-organic soils	More than half of material is <u>larger</u> than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.	Sands More than half of coarse fraction is smaller than No. 4 sieve size. (For visual classification, the No. 4 sieve size is equivalent to the No. 10 sieve size.)	Well-graded gravels, gravel-sand mixtures, little or no fines. Poorly-graded gravels, gravel-sand mixtures, little or no fines. Silty gravels, gravel-sand-silt mixtures. Clayey gravels, gravel-sand-clay mixtures. Well-graded sands, gravelly sands, little or no fines. Poorly-graded sands, gravelly sands, little or no fines. Silty sands, sand-silt mixtures. Clayey sands, sand-clay mixtures.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes. Predominantly one size or a range of sizes with some intermediate sizes missing. Nonplastic fines or fines with low plasticity. (for identification procedures see ML below.) Plastic fines (for identification procedures see CL below.) Wide range in grain sizes and substantial amounts of all intermediate particle sizes. Predominantly one size or a range of sizes with some intermediate sizes missing. Nonplastic fines or fines with low plasticity. (for identification procedures see ML below.) Plastic fines (for identification procedures see CL below.)	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. Give typical name; indicate approximate percentages of sand and gravel, max. size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses. Example: Silty sand; gravelly; about 20% hard; angular gravel particles 1/4-in. maximum size; rounded and sub-angular sand grains coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand. (SM).
GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.									
GM	Silty gravels, gravel-sand-silt mixtures.	Nonplastic fines or fines with low plasticity. (for identification procedures see ML below.)									
GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below.)									
SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.									
SP	Poorly-graded sands, gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.									
SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity. (for identification procedures see ML below.)									
SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below.)									

UNIFIED SOIL CLASSIFICATION SYSTEM

UNITED STATES INVESTIGATION
DEPARTMENT OF THE AIR FORCE

A-2

FUGRO NATIONAL, INC.



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SUMMARY OF CHEMICAL TEST RESULTS

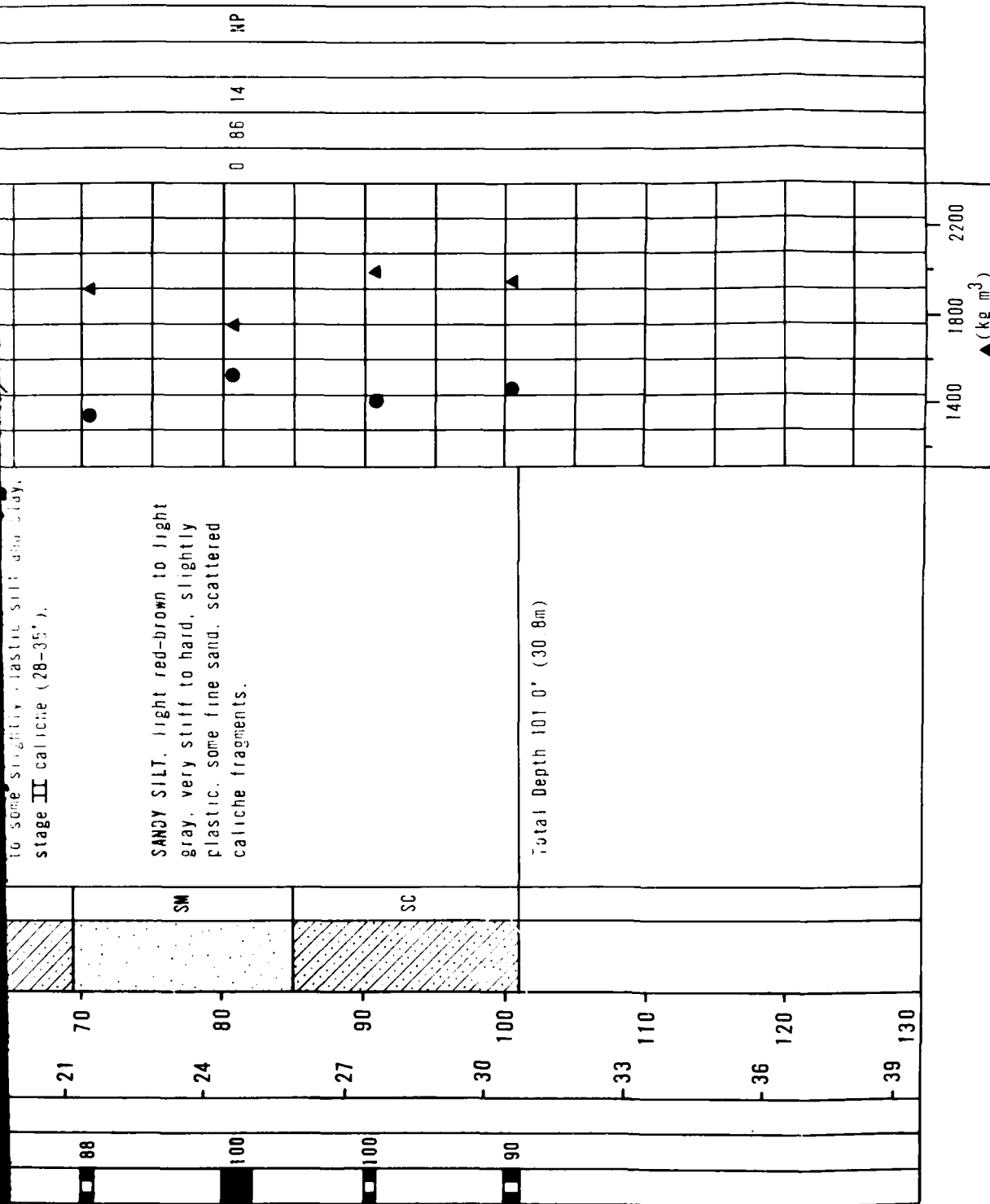
Table B-6

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS	DEPTH FEET	LITHOLOGY	USCS	SOIL DESCRIPTION	▲ (pcf)												SIEVE ANALYSIS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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SC	100	0	0	0	SC	SH	CLAYEY SAND, SANDY CLAY, SILTY SAND and SANDY SILT interbedded.	●																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										

to some slightly plastic silt and clay,
stage II caliche (28-35').

SANDY SILT, light red-brown to light
gray, very stiff to hard, slightly
plastic, some fine sand, scattered
caliche fragments.

Total Depth 101.0' (30.8m)



SAMPLE TYPES

- ☐ STANDARD PENETRATION TEST
- ☐ FUGRO DRIVE
- ☐ BULK
- ☐ PITCHER TUBE

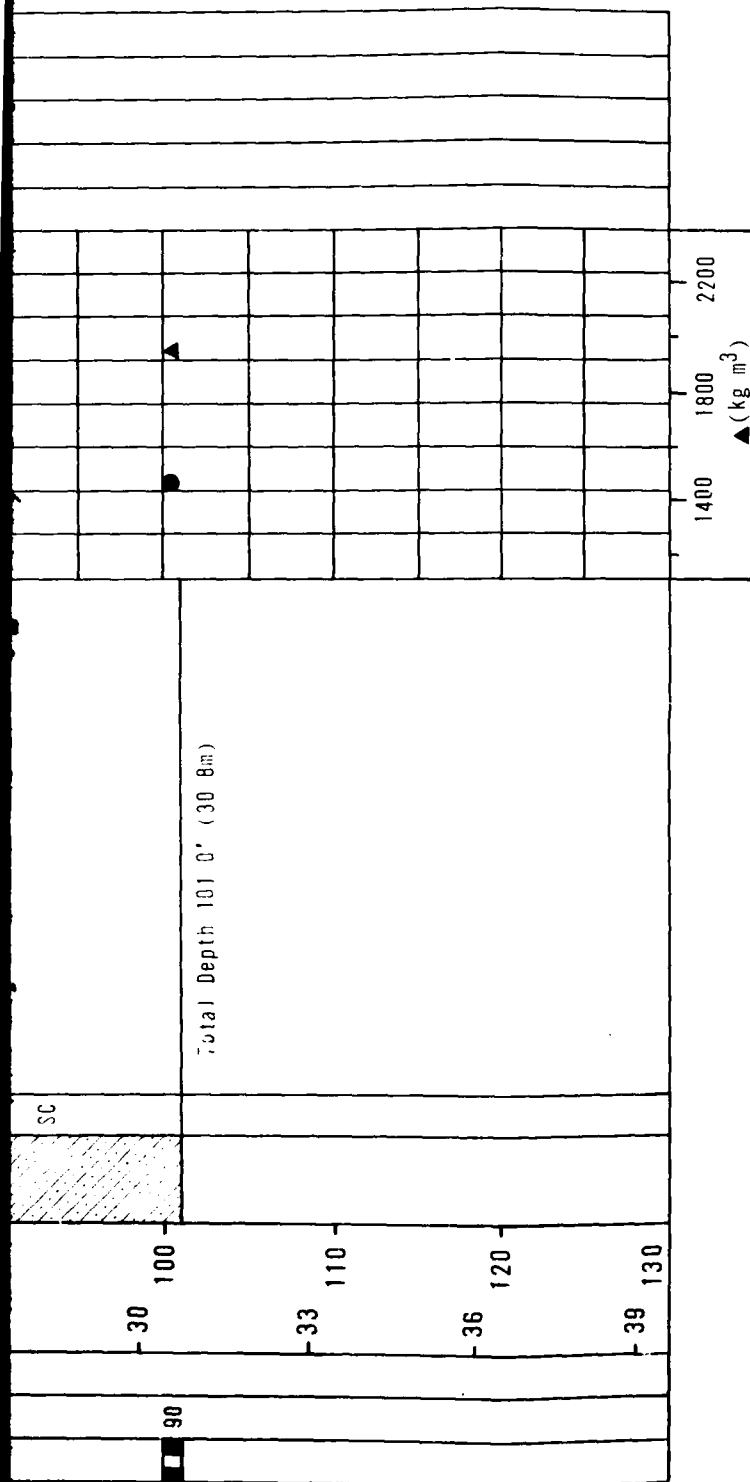
BORING DETAILS

ELEVATION : 3900' (1189m)
 DATE DRILLED : 19-20 October 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

LOG OF BOREHOLE
 MULESH
 SOUTHERN HILL

WATER SAVING INVESTIGATION
 DEPARTMENT OF THE AIR

FUGRO NA



SAMPLE TYPES

□ STANDARD PENETRATION TEST

■ FUGRO DRIVE

□ BULK

■ PITCHER TUBE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)

R - N VALUE GREATER THAN 100 BLOWS/FOOT

▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)

● - MOISTURE CONTENT (ASTM: D-2216-71)

NR - NO RECOVERY

BORING DETAILS

ELEVATION : 3900' (1189m)
 DATE DRILLED : 19-20 October 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

LOG OF BORING MS-B-1
 MULESHOE, TEXAS
 SOUTHERN HIGH PLAINS CSP

WX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMSOC

FIGURE
 B-1

FUGRO NATIONAL, INC.

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FUGRO NATIONAL INC LONG BEACH CA

F/G R/7

MX SITING INVESTIGATION. PRIME CHARACTERIZATION SITES, SOUTHERN--ETC(U)

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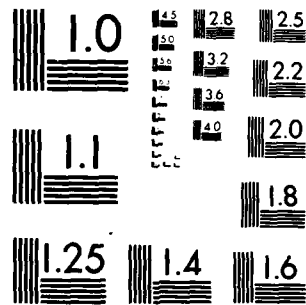
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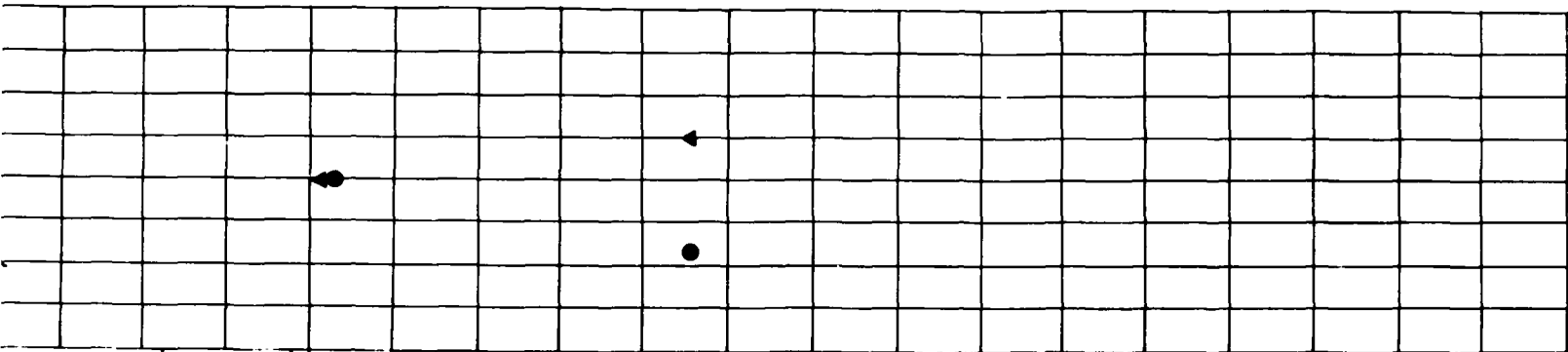
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DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

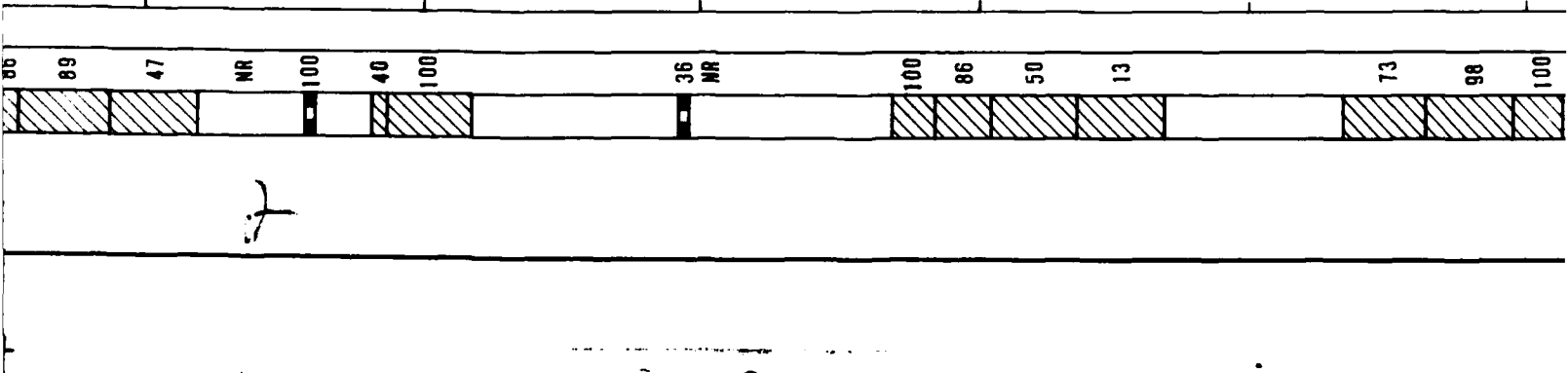
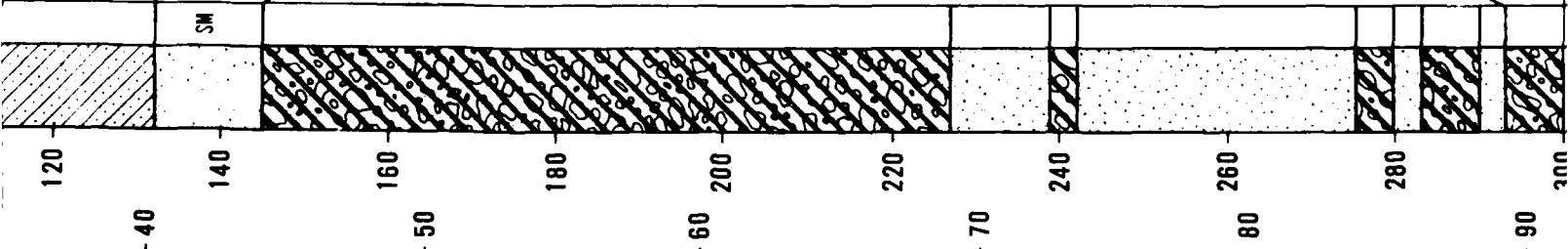
SAMPLE TYPE	% RECOVERY	N VALUE	METERS	FEET	LITHOLOGY	USCS	SOIL DESCRIPTION
	100		0	0		CL	SANDY CLAY, red-brown, stiff (0-1.5'), firm (3-9'), very stiff (9-14.5'), slightly to medium plastic, calcareous, weakly cemented, stage II caliche, layer of fractured, moderately cemented stage III caliche (1.5-3').
	80						CALICHE "CAPROCK" white to light gray, strongly to moderately cemented, massive to platy, pisolitic, brecciated, and siliceous in part.
	100						STAGE III CALICHE, light red-brown to light gray, strongly cemented, calcareous, massive, slightly fractured, some fine sand, sandy clay in fractures.
	100		-10	40			
	88						
	100						
	100						
	50			20			
	80						
	100						
	100						
	100						
	95		-30	100		SC	CLAYEY SAND, light red-gray to light gray brown, fine, poorly graded, very dense, calcareous (38-95° and 113-132°) some slightly plastic clay and silt, moderately cemented stage II to stage III caliche, massive to nodular, with friable zones.
	95						
	86						
	89			120			

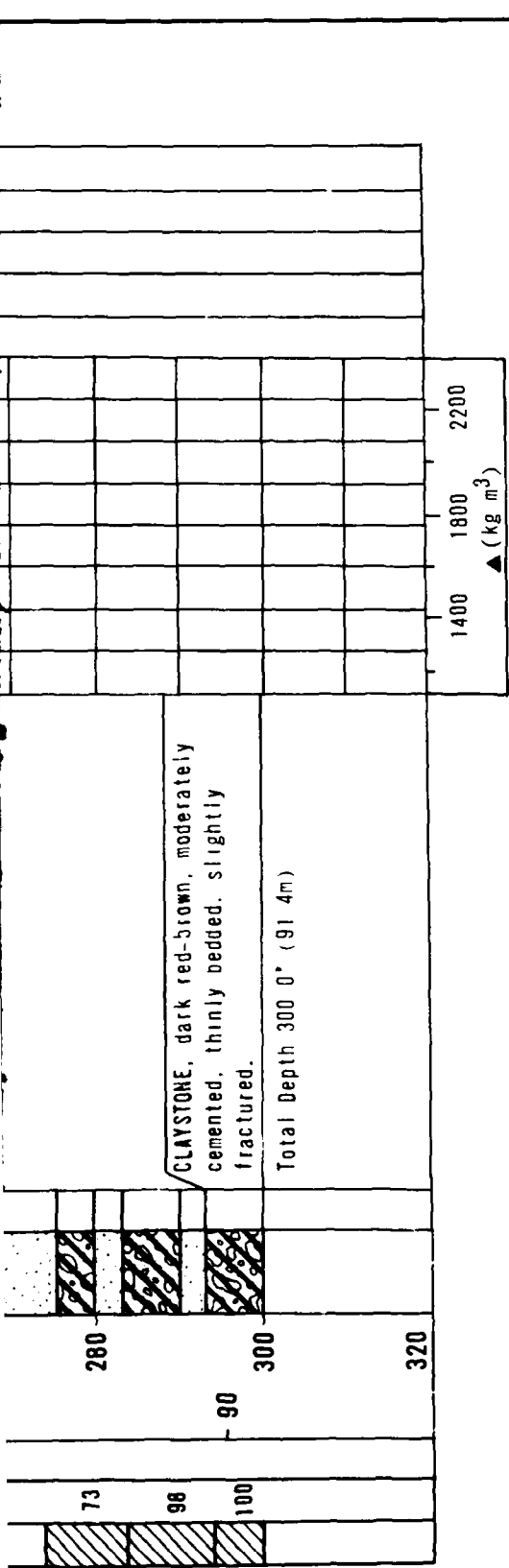


SILTY SAND, light yellow-brown to light gray brown, fine, poorly graded, very dense, calcareous, a little silt and clay.

CLAYSTONE with SHALE and SANDSTONE interbedded, dark gray to green-gray, predominantly fine grained, laminated to thinly bedded, poorly to moderately cemented, gravelly and fossiliferous in part, slightly fractured with iron stains along the fracture plains.

CLAYSTONE, dark red-brown, moderately cemented, thinly bedded, slightly fractured.





BORING DETAILS

ELEVATION : 3860' (1177m)
 DATE DRILLED : 6-11 October 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

SAMPLE TYPES

STANDARD PENETRATION TEST

FUGRO DRIVE
 BULK
 PITCHER TUBE
 CORE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)
 R - N VALUE GREATER THAN 100 BLOWS/FOOT
 ▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)
 ● - MOISTURE CONTENT (ASTM: D-2216-71)
 NR - NO RECOVERY

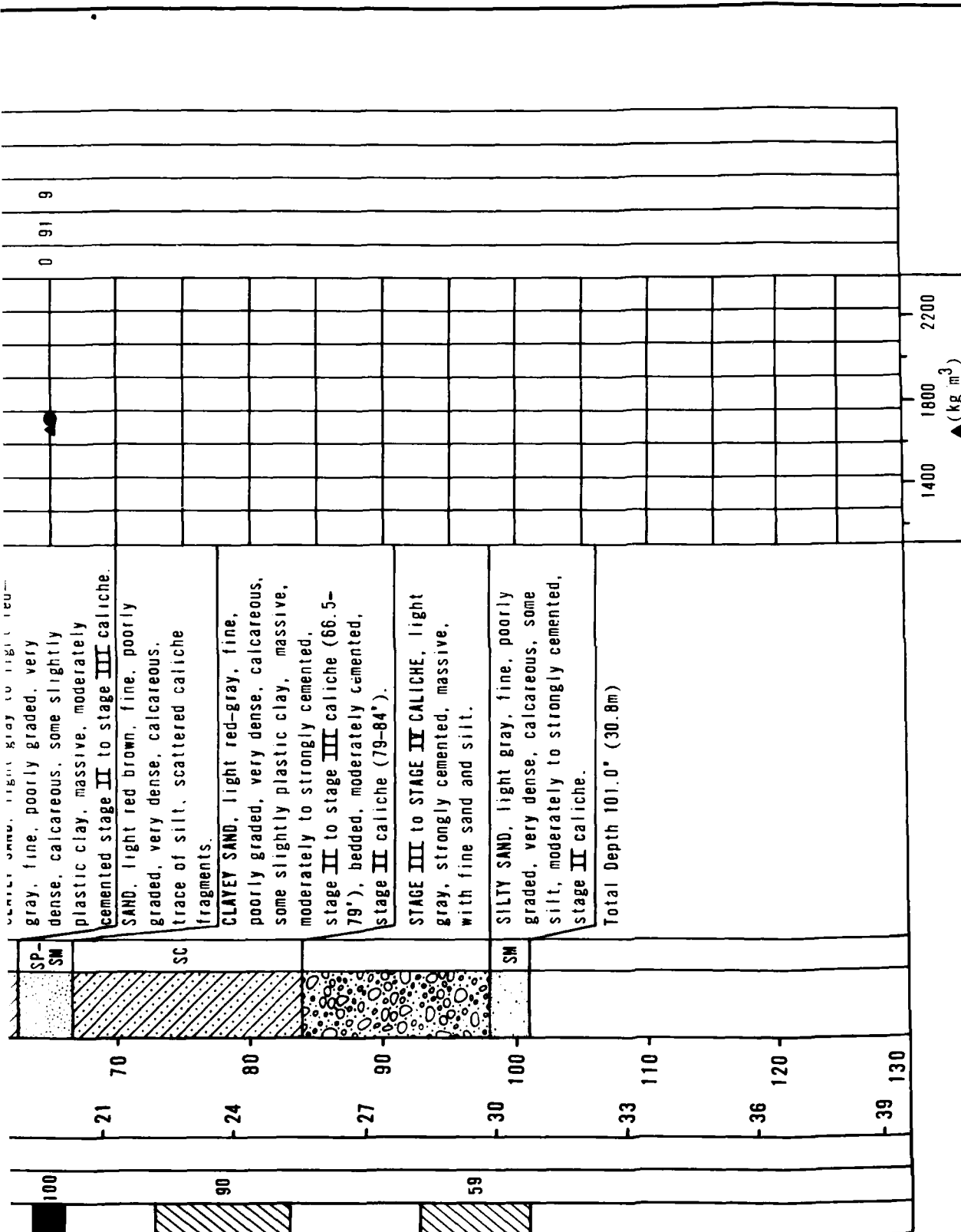
LOG OF BORING MS-B-5
 MULESHOE, TEXAS
 SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
 B-2

FUGRO NATIONAL, INC.

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH		LITHOLOGY	USCS	SOIL DESCRIPTION	▲ (pcf)															SIEVE ANALYSIS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
			METERS	FEET				80	90	100	110	120	130	140	GR	SA	FI	LL	PI																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
	73		0	0			CLAYEY SAND, red-brown, fine, poorly graded, loose (0-2') medium dense (2-19'), calcareous, some slightly plastic clay and silt, scattered, hard caliche fragments (4-13').																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							



SAMPLE TYPES

☐ STANDARD PENETRATION TEST

☒ FUGRO DRIVE

☐ BULK

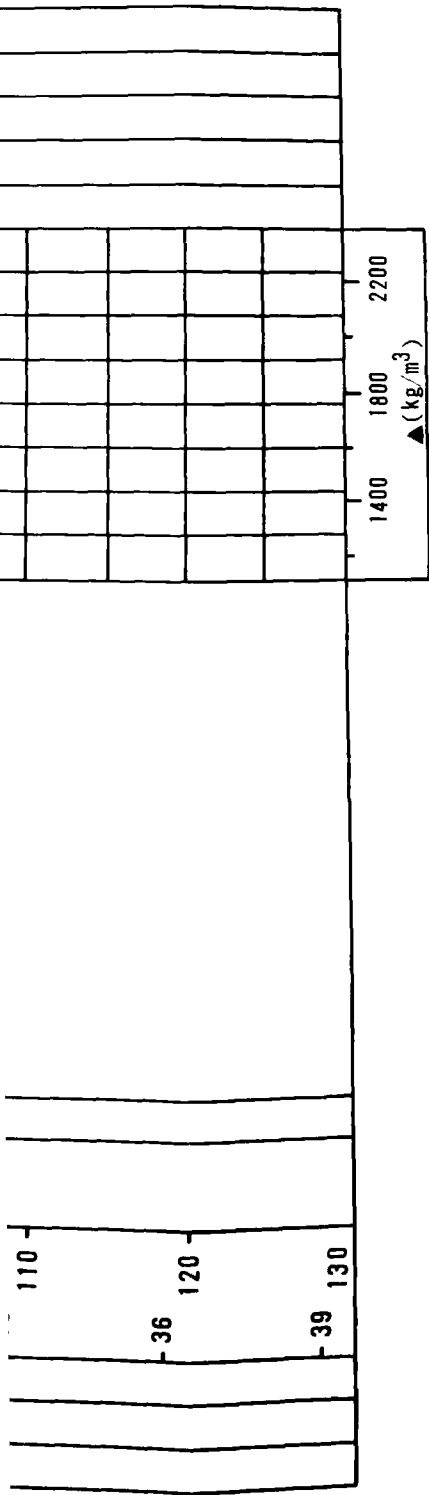
☐ PITCHER TUBE CORE

BORING DETAILS

ELEVATION : 3950' (1204m)
 DATE DRILLED : 26-27 September 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

LOG OF
 MULE:
 SOUTHERN

MX SITING INV
 DEPARTMENT OF THE A



SAMPLE TYPES

☐ STANDARD PENETRATION TEST

☐ FUGRO DRIVE

☐ BULK

☐ PITCHER TUBE CORE

☐ CORE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)

R - N VALUE GREATER THAN 100 BLOWS/FOOT

▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)

● - MOISTURE CONTENT (ASTM: D-2216-71)

NR - NO RECOVERY

BORING DETAILS

ELEVATION : 3950' (1204m)
 DATE DRILLED : 26-27 September 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

LOG OF BORING MS-B-7
 MULESHOE, TEXAS
 SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
 B-3

FUGRO NATIONAL, INC.

3

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		SM	Medium dense	SILTY SAND, red, fine, poorly graded, slightly moist.					
		2		CL	Firm	SILTY CLAY, light brown to black, highly plastic, slightly moist, varved with slightly plastic sandy silt, interbedded, slightly organic.					
	1			SM	Medium dense	SILTY SAND-SANDY SILT, light red brown, fine, poorly graded, slightly moist, stratified, layer of firm, medium plastic silty clay (3-3.5").					
		4		HL	Firm						
	2										
		6									
	3			CL	Stiff to very stiff	CLAY, black, medium plastic, calcareous, slightly moist, homogeneous, scattered, caliche nodules (below 7").	0	26	74	44	23
		8									
	4										
		10									
		12				Total Depth 12.0' (3.7m)					
	5										
		14									
		16									
	6										
		18									
		20									
		22									

TRENCH DETAILS

SURFACE ELEVATION : 3800' (1158m)
 DATE EXCAVATED : 30 November 1977
 SURFACE GEOLOGIC UNIT : A4
 TRENCH LENGTH : 22' (6.7m)
 TRENCH ORIENTATION : NS

**LOG OF TRENCH MS-T-2
 MULESHOE, TEXAS
 SOUTHERN HIGH PLAINS CSP**

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMS0

FIGURE
 B-4

UGRO NATIONAL, INC.

APPROVED BY

CHECKED BY

LOGGED BY

BULK SAMPLE	DEPTH METERS FEET	LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
						GR	SA	FI	LL	PI
	0		SM-GM	Loose	GRAVELLY SAND-SANDY GRAVEL, light brown, fine to coarse, poorly graded, subrounded, calcareous, dry with a little silt, maximum particle size 2".	41	41	18	NP	NP
	2		ML	Very stiff	CLAYEY SILT, light brown, low plasticity, calcareous, dry, homogeneous, weakly cemented, stage I caliche, trace of fine to coarse gravel, trace of fine to medium sand.					
	4		GM	Very dense	SANDY GRAVEL, light gray, fine to coarse, poorly graded, calcareous, dry with a little silt, moderately to strongly cemented, stage III caliche, fractured, maximum particle size 1.5" predominantly caliche fragments.	47	34	19		
	6									
	8									
	10									
	12									
	14									
	16									
	18									
	20									
	22									

TRENCH DETAILS

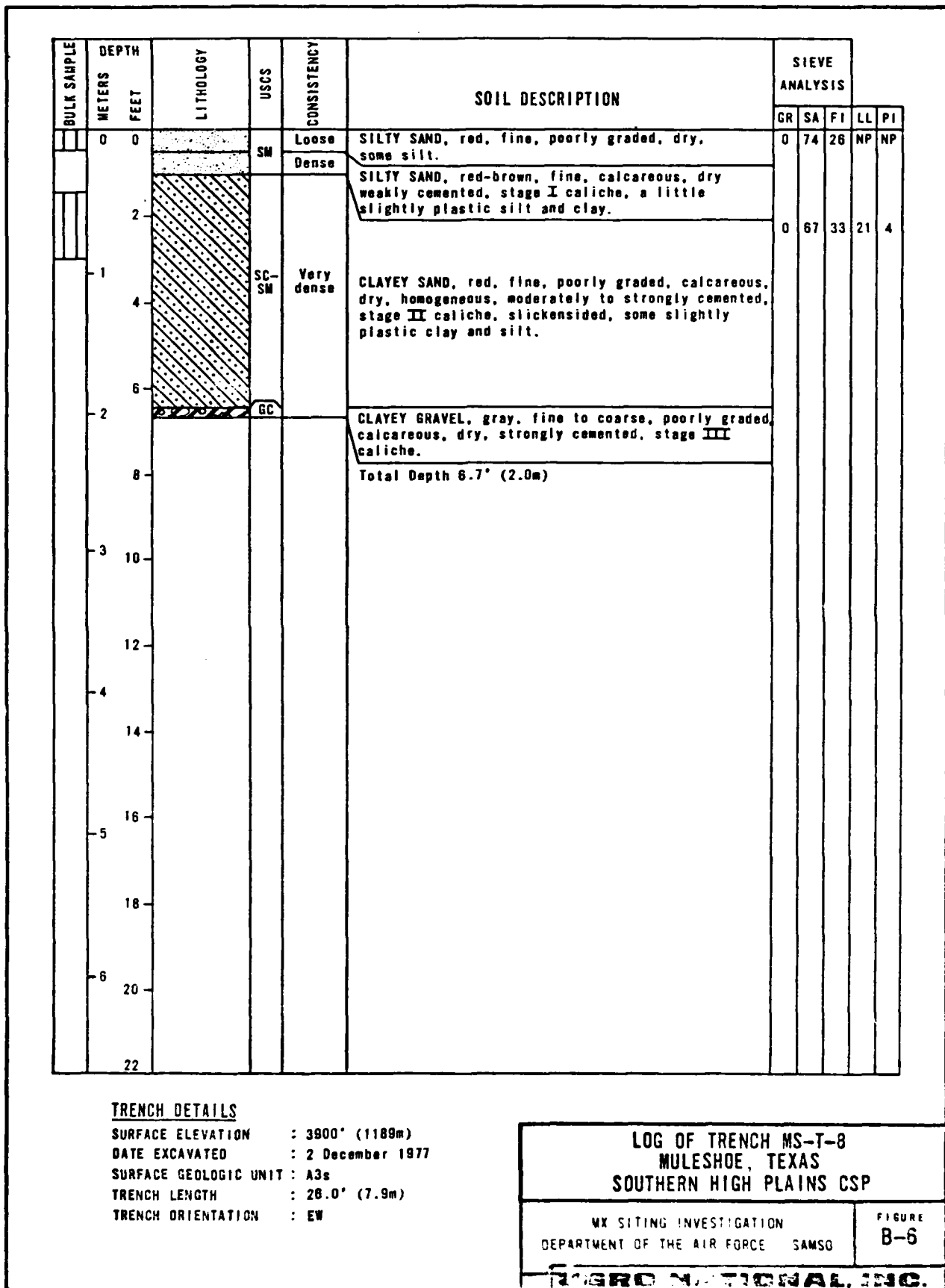
SURFACE ELEVATION : 3875' (1120m)
 DATE EXCAVATED : 2 December 1977
 SURFACE GEOLOGIC UNIT : S57a
 TRENCH LENGTH : 21.5' (6.6m)
 TRENCH ORIENTATION : NS

**LOG OF TRENCH MS-T-6
 MULESHOE, TEXAS
 SOUTHERN HIGH PLAINS CSP**

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
 B-5

UGRO NATIONAL, INC.



NOTES:

- (a) Sample types
 SS - Standard split spoon
 P - Pitcher
 D - Fugro Drive
 B - Bulk
 (b) NP - Not Plastic
- (c) USCS - Unified Soil Classification System
 (d) * Indicates the test has been performed and results are included in this report.

LIGHT						ATTERBERG LIMITS (b)			USCS (c)	IN-SITU				COMPACTED			SPECIFIC GRAVITY OF SOLIDS	TRIAXIAL (d)	UNCONFINED COMPRESSION	DIRECT SHEAR
STANDARD SIEVE NO				PARTICLE SIZE (mm)						DRY UNIT WEIGHT		MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	MAXIMUM DRY DENSITY					
SAND			SILT OR CLAY							(pcf)	(kg/m ³)				(pcf)	(kg/m ³)				
10	40	100	200	.005	.001	LL	PL	PI												
									SC	108.1	1732	5.5	26.7	0.56						
									SC/SM	104.2	1669	14.6	64.2	0.62						
									SC	117.5	1882	6.0	37.1	0.43				*		
									CL	90.3	1447	23.8	74.1	0.87				*		
									SC	105.1	1684	21.8	97.6	0.60						
									SC	113.8	1823	11.2	62.8	0.48						
									SM	121.2	1942	6.4	44.5	0.39				*		
00	43	47	22	7	6			NP	SM	108.9	1744	13.5	66.7	0.55			*			
									ML	124.7	1998	14.2	109.5	0.35						
00	47	52	36	21	19	31	18	13	SC	120.5	1930	12.2	83.0	0.40						
									SM	119.0	1906	6.5	42.3	0.42						
00	49	42	14	9	9			NP	SM	109.6	1756	12.9	64.9	0.54			2.65	*		
									SC	124.2	1990	9.6	72.7	0.36						
									SC	122.2	1958	12.0	85.4	0.38						
									</											

2

SUMMARY OF LABOR BORING MULESHOE, TEXAS, SOU
WX SITING INVEST DEPARTMENT OF THE AIR
FUGRO NAT

[illegible]

SUMMARY OF UNCONFINED COMPRESSION
TEST RESULTS
MULESHOE, TEXAS, SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

**TABLE
B-2**

UGRO NATIONAL, INC.

SUMMARY OF TRIAXIAL SHEAR TEST RESULTS
MULESHOE, TEXAS
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

**TABLE
B-3**

FUGRO NATIONAL, INC.[illegible]

FUGRO NATIONAL, INC.

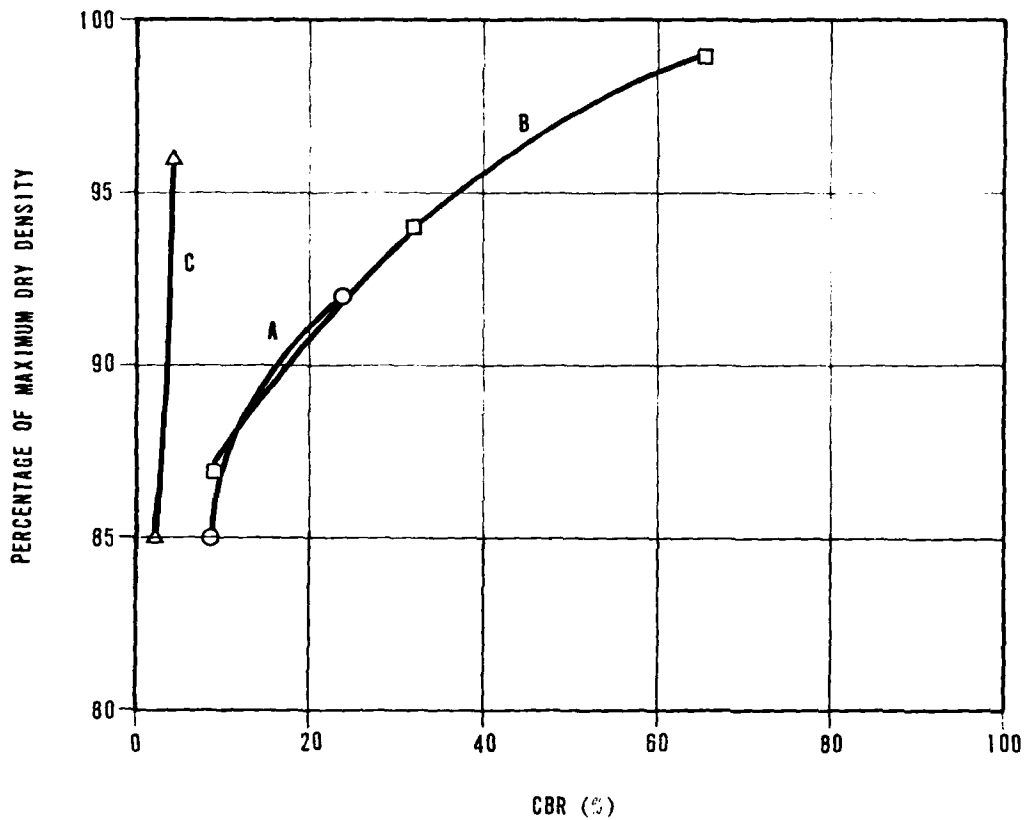
COMPOSITE SAMPLE NUMBER	SOIL TYPE	PERCENT PASSING #200	ATTERBERG LIMITS		SPECIFIC GRAVITY	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)	COMPACTED DRY DENSITY		COMPACTED MOISTURE (%)	PERCENT OF MAXIMUM DRY DENSITY	CBR (%)
			LL	PI		pct	kg/m ³		pct	kg/m ³			
A	SM	37	—	—	2.63	126.3	2023	9.3	115.5	1850	9.35	92	23.9
									106.6	1708	10.2	85	8.7
B	SC	47	22	9	2.66	125.5	2011	10.5	124.2	1990	10.4	99	62.9
									118.0	1890	10.65	94	32.1
									108.6	1740	10.9	87	9.1
C	CL	64	34	19	2.65	117.0	1874	13.0	112.7	1805	13.60	96	4.1
									99.6	1596	13.75	85	2.4

CALIFORNIA BEARING RATIO
(CBR) TEST RESULTS
MULESHOE, TEXAS, SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

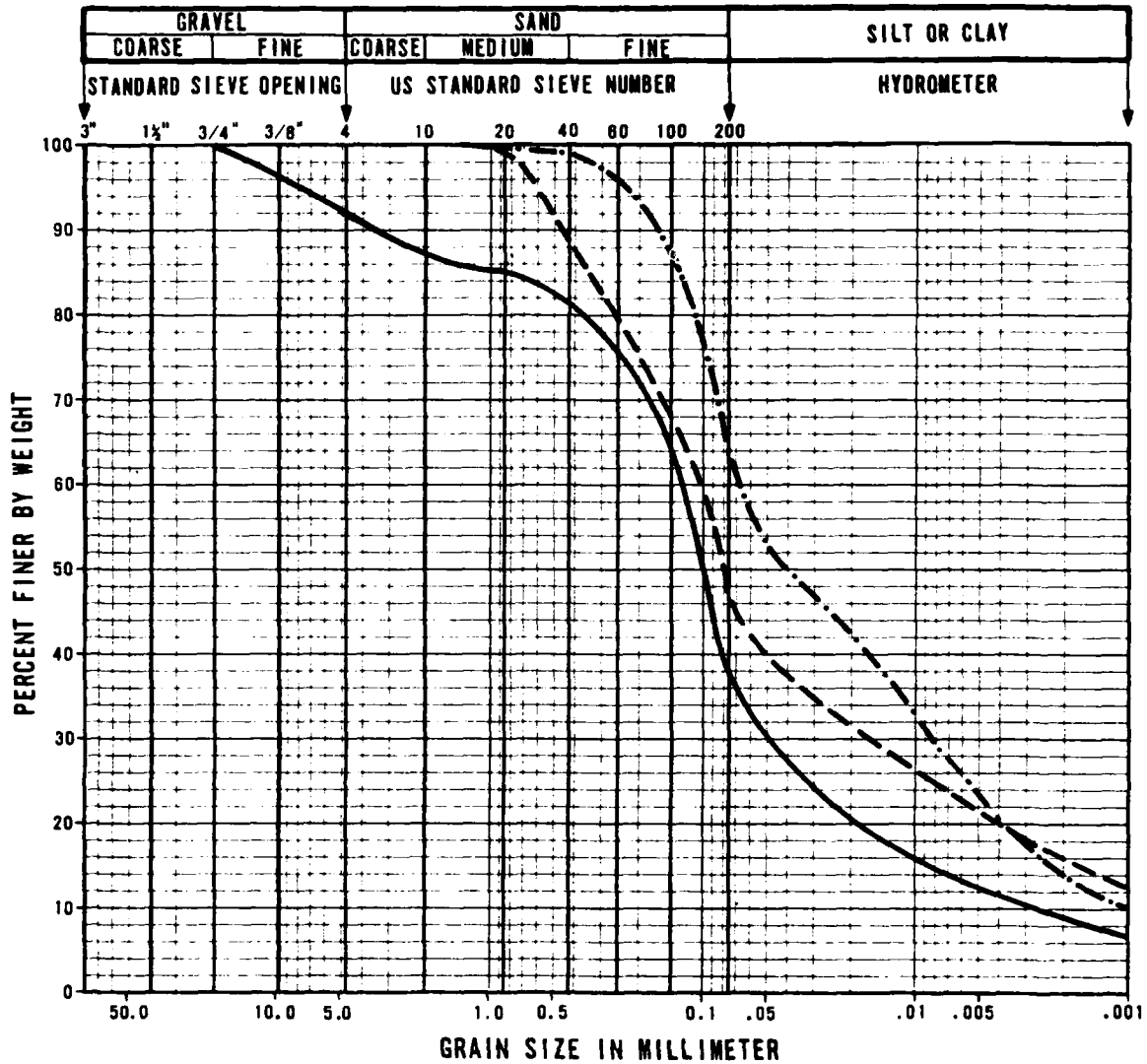
TABLE
B-5

GUARD NATIONAL, INC.



SYMBOL	COMPOSITE SAMPLE NUMBER	SOIL TYPE
○	A	SM
□	B	SC
Δ	C	CL

CALIFORNIA BEARING RATIO (CBR) CURVES MULESHOE, TEXAS, SOUTHERN HIGH PLAINS CSP	
MY SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE	SAMS0 FIGURE 8-7
FIGURE NATIONAL, INC.	



SYMBOL	COMPOSITE SAMPLE NUMBER	TRENCH NUMBER	SAMPLE INTERVAL		SOIL TYPE
			FEET	METERS	
—	A	MS-T-1	3.0 - 4.5	0.91 - 1.37	SM
—	A	MS-T-6	0.0 - 0.5	0.0 - 0.15	SM
- -	B	MS-T-7	3.0 - 4.5	0.91 - 1.37	SC
- -	B	MS-T-7	6.0 - 7.0	1.83 - 2.13	SC
- - -	C	MS-T-2	5.0 - 10.0	1.52 - 3.05	CL
- - -	C	MS-T-5	1.0 - 2.0	0.30 - 0.61	CL

GRAIN SIZE CURVES, CBR TESTS
MULESHOE, TEXAS
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
B-8

UGRO NATIONAL, INC.

[illegible]

* Weakly to moderately cemented stage III to stage IV caliche

APPENDIX C

GEOTECHNICAL DATA - ROSWELL SITE

TABLE OF CONTENTS
APPENDIX C

BORING AND TRENCH LOGS

LOG OF BORING RL-B-4	Figure C-1
LOG OF BORING RL-B-9	Figure C-2
LOG OF BORING RL-B-10	Figure C-3
LOG OF TRENCH RL-T-1	Figure C-4
LOG OF TRENCH RL-T-2	Figure C-5
LOG OF TRENCH RL-T-5	Figure C-6

SUMMARY OF LABORATORY TEST RESULTS

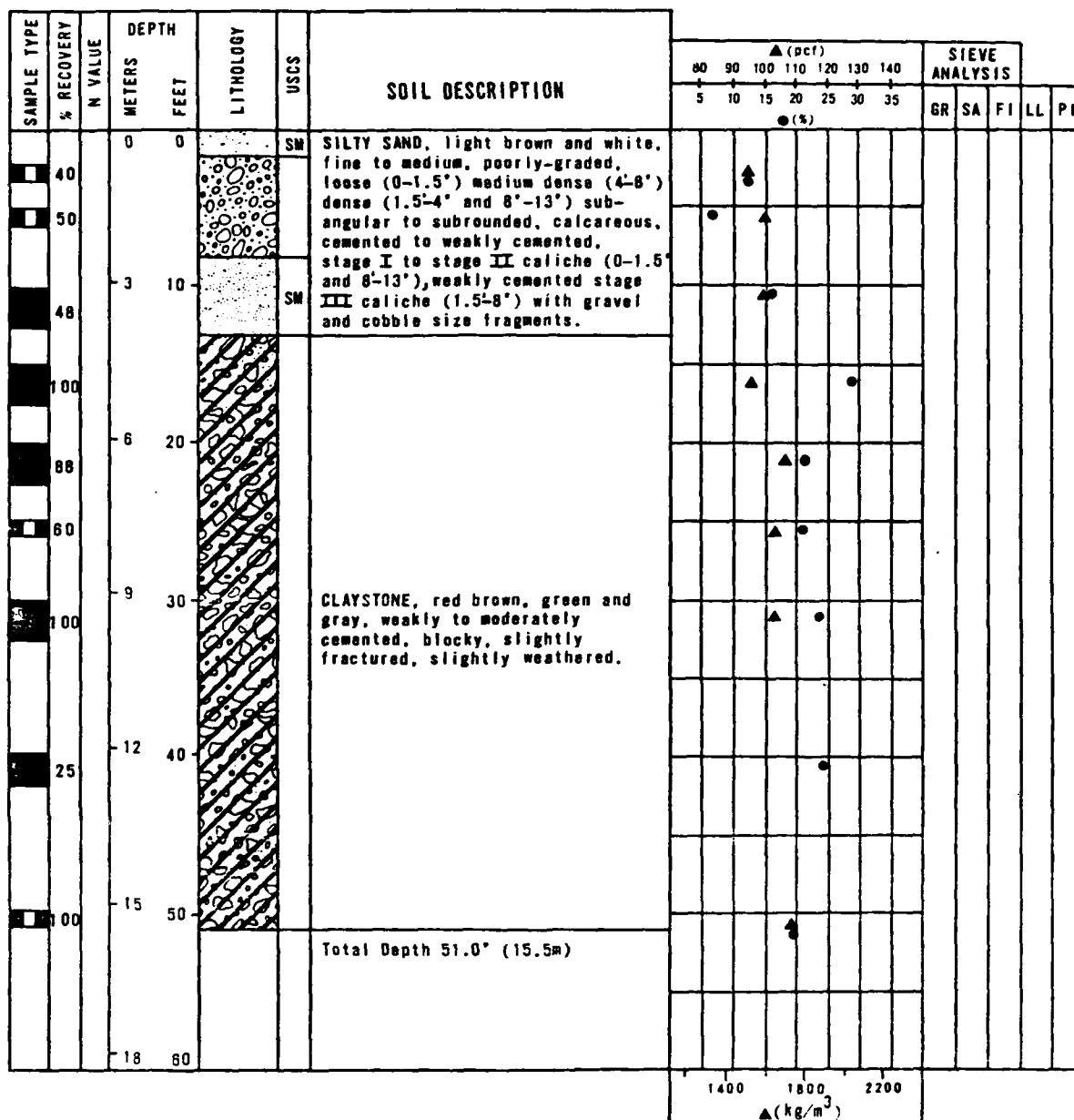
BORING RL-B-10	Table C-1
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SUMMARY OF SHEAR STRENGTH TESTS





UNCONFINED COMPRESSION TEST RESULTS	Table C-2
TRIAXIAL SHEAR TEST RESULTS	Table C-3
DIRECT SHEAR TEST RESULTS	Table C-4

SUMMARY OF CALIFORNIA BEARING RATIO (CBR) TESTS

CALIFORNIA BEARING RATIO (CBR) TEST RESULTS	Table C-5
CALIFORNIA BEARING RATIO (CBR) CURVES	Figure C-7
GRAIN SIZE CURVES, CBR TESTS	Figure C-8



SAMPLE TYPES

-  STANDARD PENETRATION TEST
 FUGRO DRIVE
 BULK
 PITCHER TUBE

ENGINEERING PARAMETERS

- N — STANDARD PENETRATION TEST (ASTM: D-1586-67)
 R — N VALUE GREATER THAN 100 BLOWS/FOOT
 ▲ — DRY UNIT WEIGHT (ASTM: D-2937-71)
 ● — MOISTURE CONTENT (ASTM: D-2216-71)
 NR — NO RECOVERY

BORING DETAILS

ELEVATION : 4000' (1219m)
 DATE DRILLED : 3 December 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

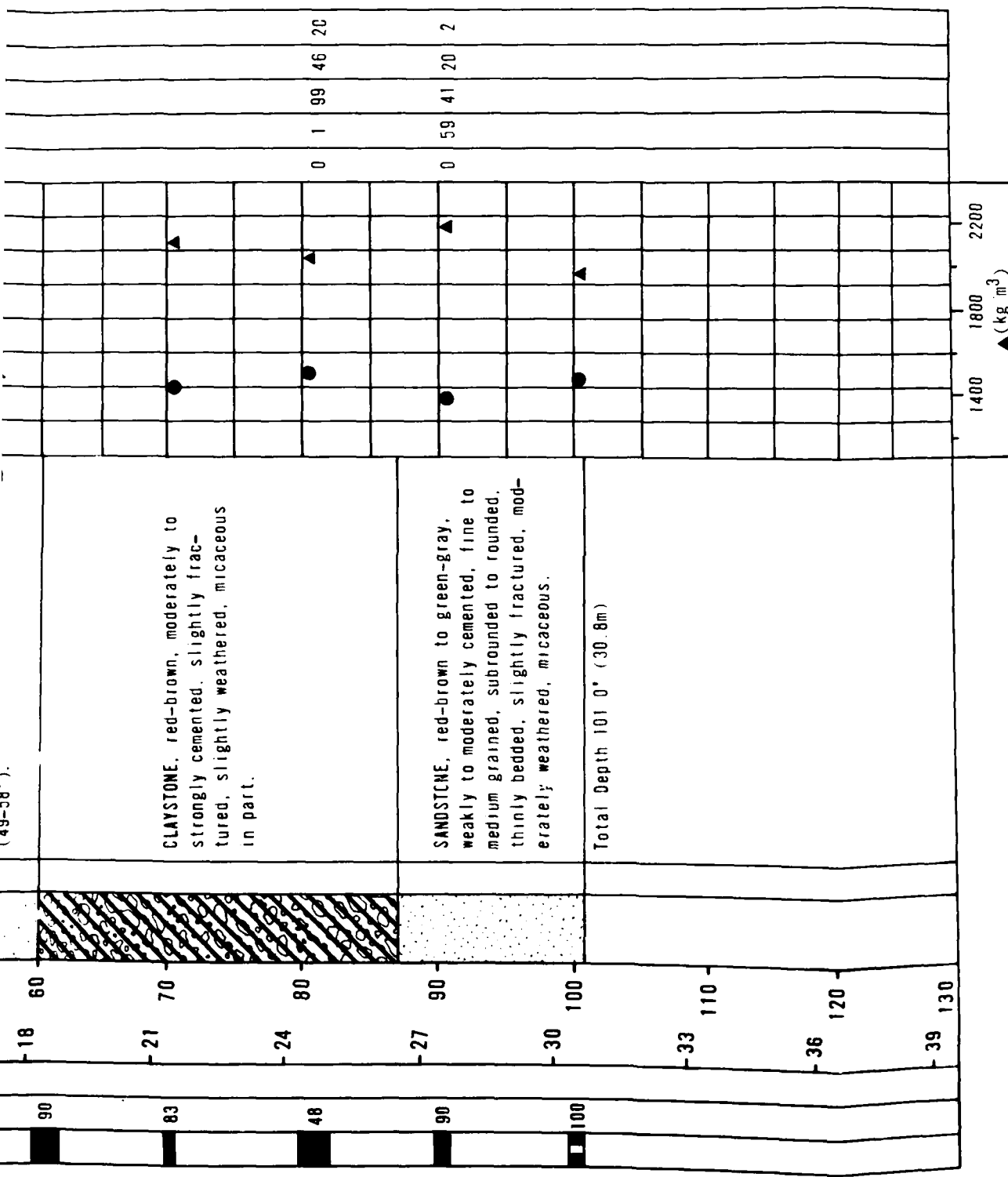
LOG OF BORING RL-B-4
 ROSWELL, NEW MEXICO
 SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SANSO

FIGURE
 C-1

FUGRO NATIONAL, INC.

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS	FEET	LITHOLOGY	USCS	SOIL DESCRIPTION
	92		0	0		SM	SILTY SAND, brown, fine, poorly graded, loose, some silt.
	96		-3	10		CH	SILTY CLAY, light gray to white, stiff to very stiff, medium to highly plastic, calcareous, stage I to stage II caliche.
	91		-6	20		SC	CLAYEY SAND, light gray to white, fine, dense to very dense, calcareous, some slightly to medium plastic clay and silt, stage II to stage III caliche.
NR 67	100		-9	30		ML	SANDY SILT, yellow-white, hard, low plasticity, calcareous, some fine sand and low plasticity clay, stage II to stage III caliche.
	80		-12	40		CL	SANDY CLAY, white, hard, slightly to medium plastic, calcareous, some fine sand and silt, stage II caliche.
	100		-15	50		SM	SILTY SAND, red-brown and white, fine, very dense, calcareous, some slightly plastic silt and clay, stage II caliche (49-58').
	90		-18	60			
			-21				



BORING DETAILS

ELEVATION : 4350' (1326m)
 DATE DRILLED : 29-30 November 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None

SAMPLE TYPES

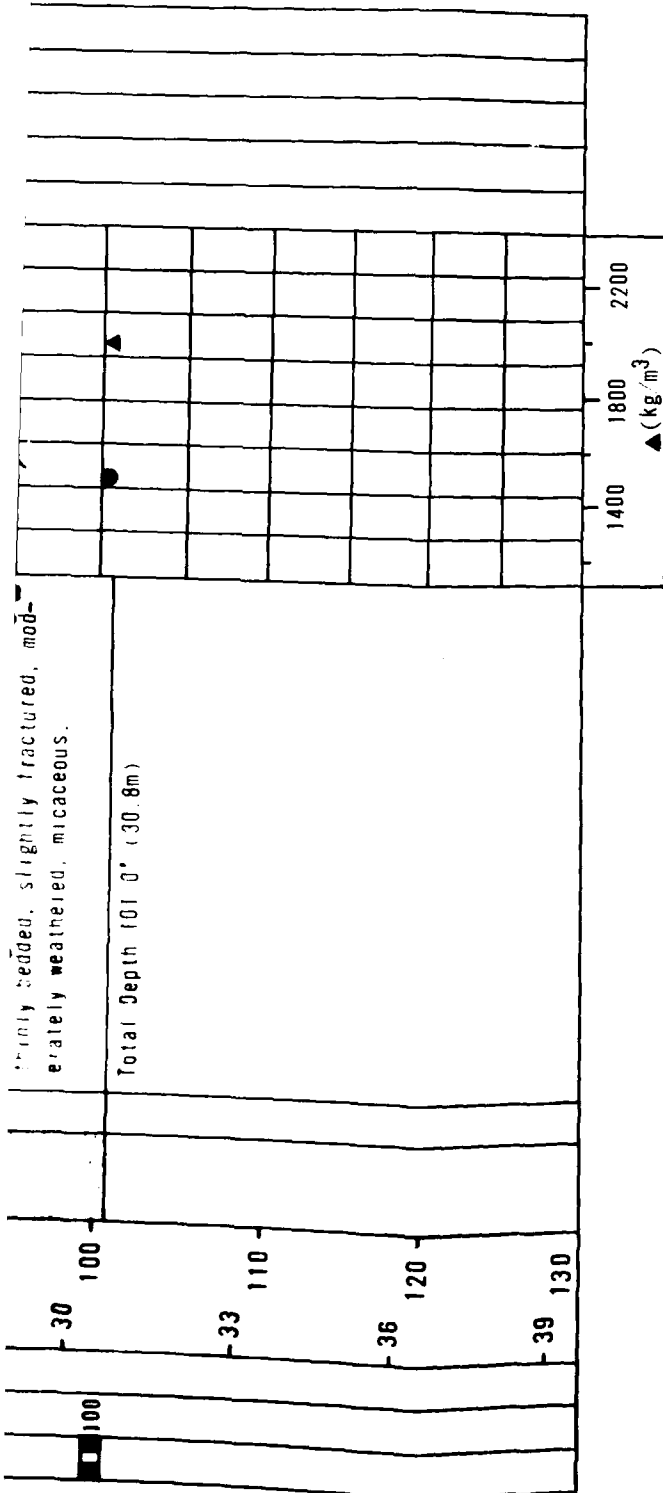
☐ STANDARD PENETRATION TEST
☒ FUGRO DRIVE
☐ BULK

LOG C
 ROSW
 SOUTHERN

FUGRO

Thinly bedded, slightly fractured, moderately weathered, micaceous.

Total Depth 101.0' (30.8m)



SAMPLE TYPES

- ☐ STANDARD PENETRATION TEST
- ☐ FUGRO DRIVE
- ☐ BULK
- ☐ PITCHER TUBE

ENGINEERING PARAMETERS

- N - STANDARD PENETRATION TEST (ASTM: D-1586-67)
- R - N VALUE GREATER THAN 100 BLOWS/FOOT
- ▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)
- - MOISTURE CONTENT (ASTM: D-2216-71)
- NR - NO RECOVERY

BORING DETAILS

- ELEVATION : 4350' (1326m)
- DATE DRILLED : 29-30 November 1977
- DRILLING METHOD : Rotary Wash
- HOLE DIAMETER : 4 7/8" (124mm)
- CASING INSTALLED : None
- WATER LEVEL : Not Encountered

LOG OF BORING RL-B-9
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

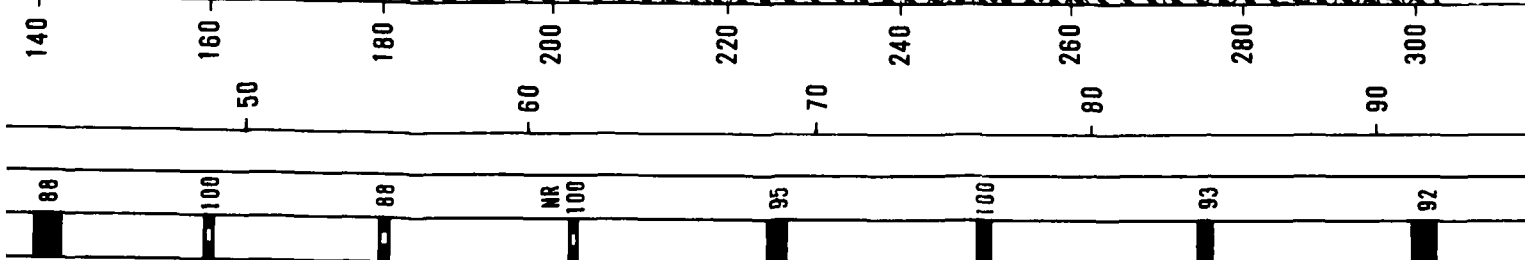
FIGURE
C-2

FUGRO NATIONAL INC.

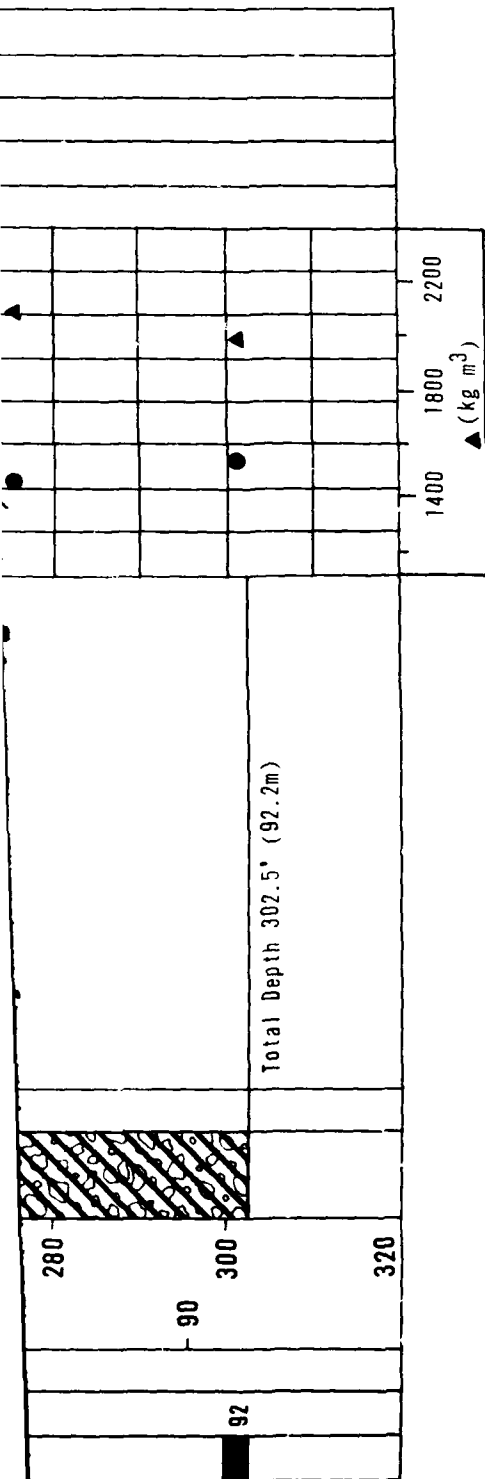
SAMPLE TYPE	% RECOVERY	N VALUE	METERS	FEET	LITHOLOGY	USCS	SOIL DESCRIPTION
	76		0	0	SM	SC	SILTY SAND, brown, fine, poorly graded. loose, some silt.
	50						
	100						
	88						
	82						
	86						
	100						
	100						
	89						
	100						
	100						
	73						
	100						
	83						
	86						

SANDSTONE and CLAYSTONE, interbedded, red-brown to green-gray, moderately to strongly cemented, fine to medium grained, subrounded to rounded, thinly bedded, slightly fractured, moderately weathered, micaceous.

Total Depth 302.5' (92 m)



2



SAMPLE TYPES

■ STANDARD PENETRATION TEST

■ FUGRO DRIVE

□ BULK

■ PITCHER TUBE

▨ CORE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)

R - N VALUE GREATER THAN 100 BLOWS/FOOT

▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)

● - MOISTURE CONTENT (ASTM: D-2216-71)

NR - NO RECOVERY

BORING DETAILS

ELEVATION : 4040' (1231m)
 DATE DRILLED : 30 Nov - 2 Dec 1977
 DRILLING METHOD : Rotary Wash
 HOLE DIAMETER : 4 7/8" (124mm)
 CASING INSTALLED : None
 WATER LEVEL : Not Encountered

LOG OF BORING RL-B-10
 ROSWELL, NEW MEXICO
 SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
 C-3

FUGRO NATIONAL INC.

BULK SAMPLE	DEPTH		LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
	METERS	FEET					GR	SA	FI	LL	PI
	0	0		SM	Dense	SILTY SAND, brown, fine, poorly graded, dry, trace of angular gravel and cobbles with calcareous coating, maximum particle size 3.5" stage I caliche.	4	59	37	18	2
	2										
	1										
	4			GM-GP	Very dense	SANDY GRAVEL, light gray, fine to coarse, poorly graded, angular, calcareous, dry, moderately cemented (1.4-5") strongly cemented (5-8.1') fractured stage III caliche, maximum particle size 5".	69	24	7		
	6										
	2										
	8						87	25	8		
						Total Depth 8.1' (2.5m)					
	3	10									
		12									
	4	14									
		16									
	5	18									
		20									
	6	22									

TRENCH DETAILS

SURFACE ELEVATION : 4535' (1382m)
 DATE EXCAVATED : 8 December 1977
 SURFACE GEOLOGIC UNIT : SSTo
 TRENCH LENGTH : 21.5' (6.6m)
 TRENCH ORIENTATION : NS

LOG OF TRENCH RL-T-1
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE GANSO

FIGURE
 C-1

UGRO NATIONAL, INC

CHECKED BY: [signature] APPROVED BY: [signature] LOGGED BY: [signature]

BULK SAMPLE	DEPTH METERS FEET	LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS				
						GR	SA	FI	LL	PI
	0		SM	Medium dense	SILTY SAND, brown, fine, poorly graded, angular, calcareous, dry, trace of gravel and cobbles, maximum particle size 3.5", stage II caliche, some silt.	5	74	21	NP	NP
	2									
	1					90	9	1		
	4									
	6									
	2			Dense	STAGE III CALICHE, light gray, weakly cemented, calcareous, fractured, trace of fine to coarse sand.					
	8									
	3		SM		SILTY SAND, light brown, fine, poorly graded, angular, calcareous, slightly moist, weakly cemented, stage II caliche, maximum size of nodules 5", some silt.					
	10									
	12									
	4				Total Depth 13.0' (4.0m)					
	14									
	16									
	5									
	18									
	6									
	20									
	22									

TRENCH DETAILS

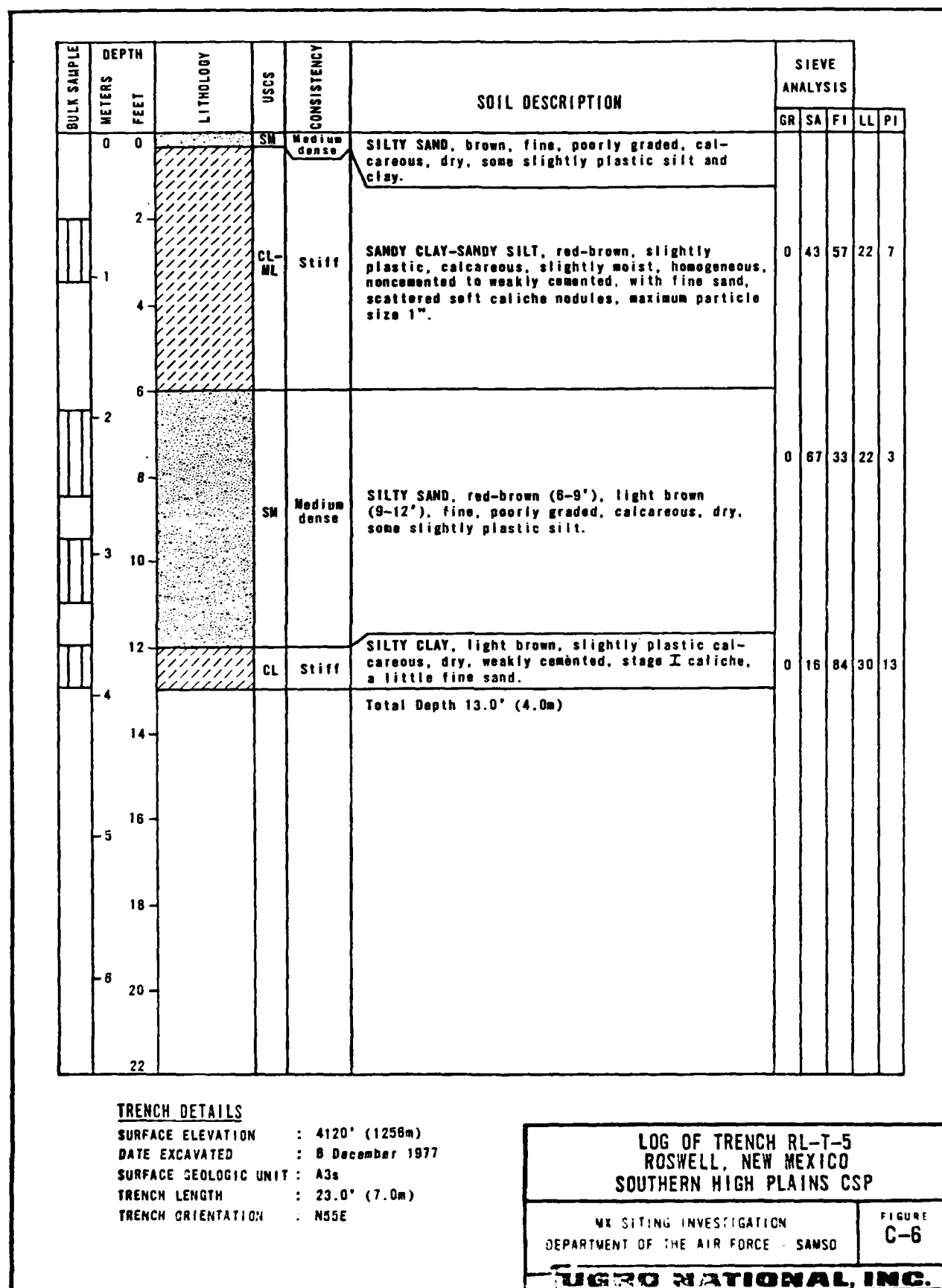
SURFACE ELEVATION : 4000' (1219m)
 DATE EXCAVATED : 8 December 1977
 SURFACE GEOLOGIC UNIT : A2r
 TRENCH LENGTH : 23.0' (7.0m)
 TRENCH ORIENTATION : N15W

LOG OF TRENCH RL-T-2
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
 DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
 C-5

UGRO NATIONAL, INC.



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- (a) Sample types
 SS - Standard split spoon
 P - Pitcher
 D - Fugro Drive
 B - Bulk
 (b) NP - Not Plastic
- (c) USCS - Unified Soil Classification System
 (d) * Indicates that test has been performed
 and results are included in this report.

PARTICLE SIZE (mm)			ATTERBERG LIMITS (b)			USCS (c)	IN-SITU					COMPACTED			SPECIFIC GRAVITY OF SOLIDS	TRIAXIAL (d)	UNCONFINED COMPRESSION	DIRECT SHEAR	CONSOLIDATION	CHEMICAL	RELATIVE DENSITY
SILT OR CLAY			LL	PL	PI		DRY UNIT WEIGHT		MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)							
200	.005	.001					(pcf)	(kg/m ³)				(pcf)	(kg/m ³)								
						SC	98.3	1575	13.1	49.5	0.71										
						SC	116.4	1865	11.2	67.5	0.45										
1	14	13	28	19	9	SC	110.6	1772	10.9	56.4	0.52					*					
						CL	117.0	1874	15.7	96.3	0.44										
1	25	6	20	17	3	SM	110.4	1762	11.9	61.2	0.52										
						CL	110.7	1773	14.3	74.0	0.52			2.67		*			*		
						CL	137.2	2198	8.5	101.2	0.23										
						CH	143.7	2302	5.3	82.5	0.17										
						SM	130.4	2089	11.2	103.1	0.29										
						SM	136.5	2187	10.6	122.4	0.23										
1	12	8	29	26	3	SM	129.1	2068	13.8	121.7	0.30										
						SM	119.0	1906	14.7	95.3	0.42										
						SM	117.3	1879	16.8	103.8	0.44										
						SM	137.9	2209	14.1	171.1	0.22										
						SM	122.2	1958	13.6	97.3	0.38										
						CL	117.8	1887	17.8	111.4	0.43										
						CL	125.0	2002	11.4	88.7	0.35										
						CL	119.2	1910	14.8	96.9	0.41										
						CL	131.3	2103	10.9	104.1	0.28										
						CH	122.4	1961	12.9	92.6	0.38										
						CH	130.1	2084	11.4	104.4	0.30										
						CH	125.0	2002	13.4	104.0	0.35										
												</									

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SUMMARY OF LABORATORY TEST RESULTS	
BORING RL-B-10	
ROSWELL, NEW MEXICO, SOUTHERN HIGH PL	
MX SITING INVESTIGATION	
DEPARTMENT OF THE AIR FORCE	SAMSO
FUGRO NATIONAL	

SUMMARY OF LABORATORY TEST RESULTS BORING RL-B-10 ROSWELL, NEW MEXICO, SOUTHERN HIGH PLAINS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMS0	TABLE C-1
FUGRO NATIONAL, INC.	

*Weakly to moderately cemented claystone

SUMMARY OF UNCONFINED COMPRESSION
TEST RESULTS
ROSWELL, NEW MEXICO, SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

TABLE
C-2

FUGRO NATIONAL, INC.

[illegible]

*Weakly to moderately cemented claystone

****Weakly to moderately cemented sandstone**

SUMMARY OF TRIAXIAL SHEAR TEST RESULTS
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE
C-3

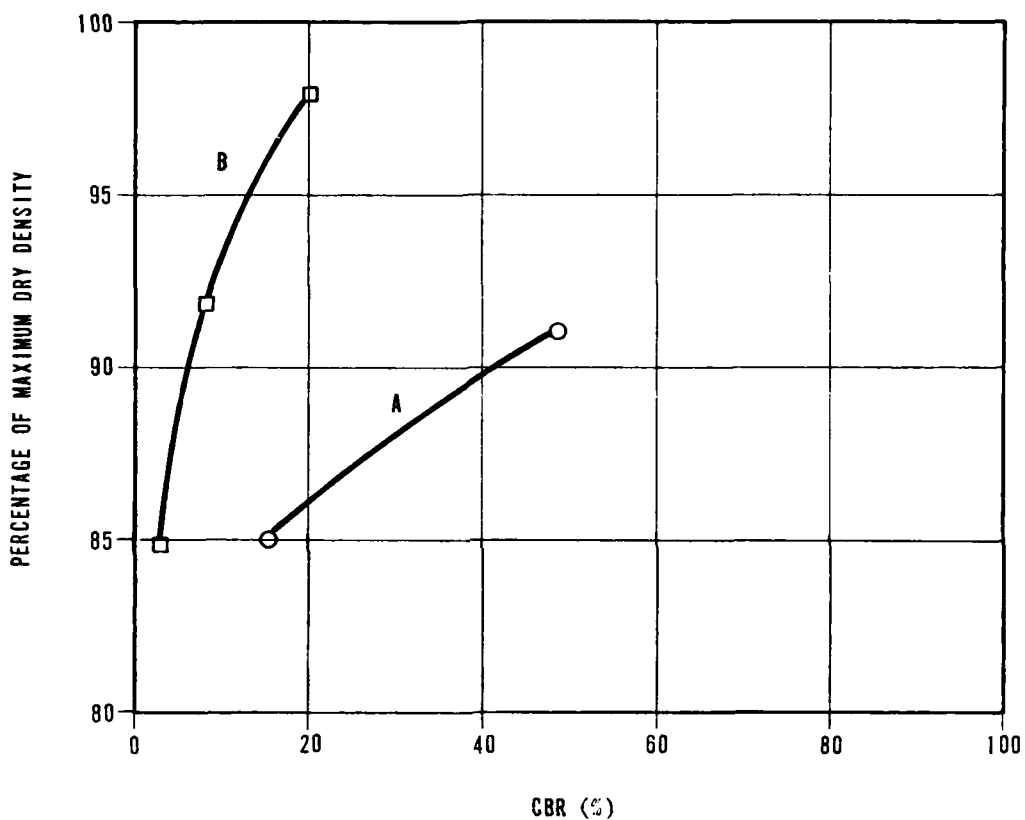
FUGRO NATIONAL, INC.

CALIFORNIA BEARING RATIO
(CBR) TEST RESULTS
ROSWELL, NEW MEXICO, SOUTHERN HIGH PLAINS CSP

COMPOSITE SAMPLE NUMBER	SOIL TYPE	PERCENT PASSING #200	ATTERBERG LIMITS		SPECIFIC GRAVITY	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)	COMPACTED DRY DENSITY		COMPACTED MOISTURE (%)	PERCENT OF MAXIMUM DRY DENSITY	CBR (%)			
			LL	PI		pcf	kg/m ³		pcf	kg/m ³						
A	SM	35	—	—	2.63	122.0	1954	11.7	111.0	1778	12.6	91	48.2			
									103.2	1653	11.7	85	16.3			
B	CL	61	26	12	2.62	128.0	2051	10.0	125.9	2017	10.2	98	20.5			
									118.0	1890	10.3	92	9.1			
									108.7	1741	10.4	85	4.0			

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE
C-5



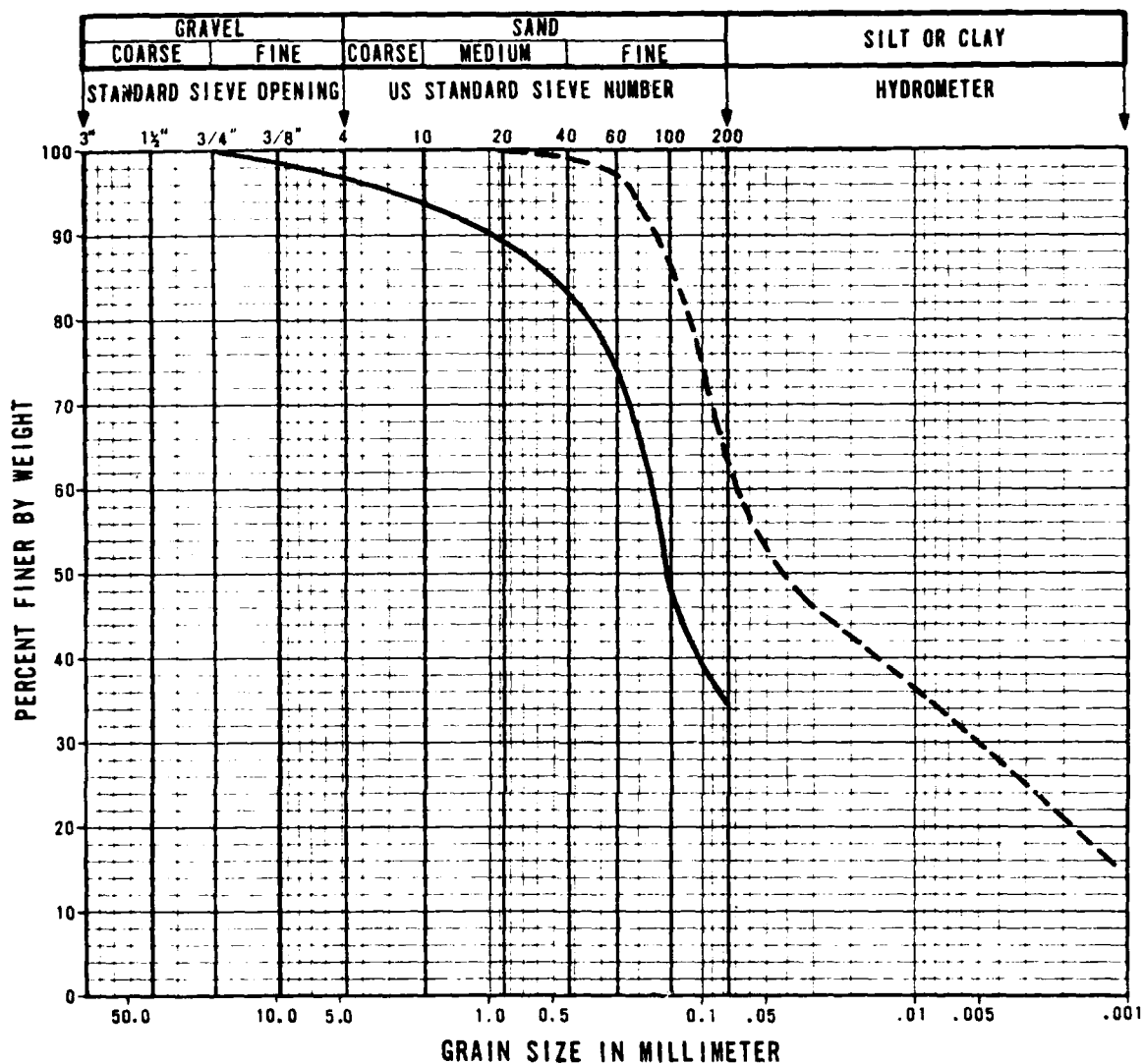
SYMBOL	COMPOSITE SAMPLE NUMBER	SOIL TYPE
○	A	SM
□	B	CL

CALIFORNIA BEARING RATIO
(CBR) CURVES
ROSWELL, NEW MEXICO, SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
C-7

FOR INFORMATIONAL USE



SYMBOL	COMPOSITE SAMPLE NUMBER	TRENCH NUMBER	SAMPLE INTERVAL		SOIL TYPE
			FEET	METERS	
—	A	RL-T-4	4.0 - 6.0	1.22 - 1.83	SM
		RL-T-2	0.0 - 1.0	0.0 - 0.31	
---	B	RL-T-5	12.0 - 13.0	3.66 - 3.96	CL
		RL-T-5	2.0 - 3.5	0.61 - 1.07	

GRAIN SIZE CURVES, CBR TESTS
ROSWELL, NEW MEXICO
SOUTHERN HIGH PLAINS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS0

FIGURE
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UNITED STATES ARMY

END

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